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# POONA SEWERAGE SCHEME

AN

# ADDRESS

TO

# THE MUNICIPALITY OF POONA

54769

BY

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# AN ADDRESS

TO

# The Municipality of Poona on their Sanitary Requirements.

GENTLEMEN,

*Death Rate.*

During the last two years plague has unfortunately contributed to an abnormally high death-rate for your town; but taking the Administration Reports prior to 1896-97, I find that out of an estimated population of 118,790, the number of deaths varied from 3,157 to 3,515, and the ratio per thousand of the above was from 26·57 to 29·59. The average yearly number of deaths for these five years is just under 3,300, and the average death-rate nearly 28 per 1,000.

2. The statistics of various towns in Europe have established the fact that the normal yearly death-rate of towns should not, and need not, exceed 20 to 25 per 1,000; also, that for every death by preventable disease, there are 17 to 25 cases of illness of a more or less severe type, which may be avoided. The death-rate last month of 33 of the largest towns in England varied from 15·7 to 18·4 per 1000 per annum, on their total population.

3. Where the yearly death-rate in a town normally exceeds 20 to 25 per 1,000, and the average duration of life of the inhabitants is less than 40 to 50 years, it is almost always the *direct* consequence of either an impure water-supply, or of a soil contaminated by sewage, or both; and the removal of these injurious influences *invariably* has an immediate effect in at once reducing the death-rate and the amount of sickness, and so prolonging the lives of the inhabitants.

*Present Water Supply.*

4. It is surely an anomaly that a town of the size, wealth and importance of Poona should depend for a large part of its water-supply on the 1,300 or more wells sunk in a contaminated subsoil; and on the dipping cisterns fed by old leaky aqueducts, which are liable to be, and frequently must be, contaminated; and on taps served by a very low pressure. The history of jail wells in this country, and several cases within my personal experience, show that wells and dipping cisterns *are*, at times, polluted and infected by persons drawing water from them in the usual native fashion. The risk under this head is in direct proportion to the number of persons drawing water; and no one can tell when this risk, which may result in a serious epidemic, will be incurred. From the Katraj Tank and the Karakwasla Canal you can get any reasonable supply of fairly good water; but filter beds, high-level reservoirs

with machinery to lift the pure water into the reservoirs, and a proper system of distribution under a minimum pressure of 20 to 25 feet, by means of iron pipes, with stand-posts and other services, are necessary additions which the Municipality should make in the near future. With a drainage system in existence, as I hope it soon will be, house connections for water can be given freely to those who can pay for them ; and for the poorer people, the public services should be so distributed that no one need have to go more than 300 or 400 feet for their water.

*Hamburg Cholera Epidemic.*

5. Before leaving this subject I would like to mention one striking instance of the protective value of filters for a water-supply ; and of the sudden way in which danger may arise after years of immunity, and develop into an epidemic, where this protection is neglected. In Germany there are three towns, Hamburg, Altona, and Wandsbeck, which immediately border on one another, and practically form one city, but are supplied with water from different sources. Wandsbeck gets its water direct from a lake, which is practically unpolluted. Hamburg gets its water from the River Elbe, above the city, where it is *usually* fairly pure; and Altona gets its supply from the same river, but below the city, and *after* the river has received the sewage of about 800,000 people ; but the Municipality of Altona paid particular attention to the filtering of their supply; whilst Hamburg neglected doing so, as their supply was fairly pure. A few years ago Hamburg suffered terribly, and for months, from cholera ; whilst Wandsbeck and Altona were almost free from the disease. The most surprising phenomena of the epidemic came to light on the frontier of Hamburg and Altona. Here all the conditions of importance in this connection, *viz.*, soil, buildings, sewerage, population, &c., were precisely similar, *except* as regards the water-supply ; and yet the cholera in Hamburg spread only to where Altona began, and *stopped there.* In one street, which forms the boundary of the two towns for a considerable distance, the Hamburg side of the street was attacked by cholera, whilst the Altona side was free from it. In one mixed group of crowded houses, the cholera traced out with sharp precision *the frontier of the water-supply* of the two cities.

6. The original cause of the epidemic was that cholera germs had got into the river water from a cholera patient on board one of the ships, and had spread and multiplied rapidly. Hamburg took no precautions about protecting its water-supply, as the source had hitherto been fairly pure; whilst Altona was most careful in this respect. In the former case the cholera germs happened to find a favouring period, and caused a terrible epidemic ; in the latter case, at the *same* period, the careful filtration practically stopped these germs from passing into the distribution system of the water-supply, although the original supply was from a far more polluted source than that of Hamburg. The contrast is the more striking when it is remembered that Hamburg is one of the best drained cities in the world ; that is, it is furnished with works which convey the sewage and sullage out of the houses, and away from the streets, rapidly to

beyond the limits of the city. Fortunately, there are not many infectious diseases, the germs of which can be spread by water ; and only two are certainly known, *viz.*, cholera and typhoid fever ; both have other ways of spreading, but there is no doubt that water is a suitable medium for them ; and under favouring circumstances it can, if polluted with these germs, cause an epidemic.

*Poona Water Supply Dangerous.*

7. Now could there possibly be a more practical proof of the necessity for, and the value of, filtering your water-supply, and distributing it in such a way that it could not be polluted? This City has, I believe, hitherto enjoyed immunity from typhoid, just as Hamburg had from cholera ; but who can tell when the Karakwasla Canal (from which a large portion of your water-supply is obtained) may be contaminated accidentally, as the Hamburg river was; resulting, if other conditions happened at the time to be favourable to the disease germs, in a disastrous epidemic. In your case you have two *additional* dangers, in your dipping cisterns and wells. The former may at *any* time be contaminated with disease germs, either blown in, or communicated from the pots of those drawing water ; the latter ( from which one-third of your supply is obtained ), in addition to the same risk as the dipping cisterns, are *also* liable to contamination from the subsoil. It is obvious that the land on which a crowded and undrained city has existed for centuries, must be contaminated ; it is also obvious that in a large city isolated cases of infectious disease may occur, or be imported, at any time ; and it is a well ascertained fact that the germs of such a disease are capable of spreading in the subsoil, if not properly dealt with, and contaminating the water in a neighbouring well, from which they can spread to other wells. All that is necessary to produce an epidemic in such cases are concurrent circumstances, of weather, &c., favourable to the spread of the germs. Hitherto these have fortunately not occurred here, but no one can possibly say when they will occur. As you have the means at hand which will *certainly* remove this risk, surely it is not a wise policy to put off availing yourselves of this means of continuing your immunity indefinitely.

*Poona Conservancy.*

8. Again, is it not apparent to everyone that the air you daily breathe is foul with the decomposing urine and sullage water which stagnates, more or less, in the side gutters and drains of every street and lane ; which gutters are more or less choked by rubbish, and covered in by slabs in front of the houses? Is not the disposal of your night soil and street sweepings imperfectly carried out? Are not your latrines insufficient in number, and not cleaned often enough, with the natural consequence that some of your roads and open spaces are used as latrines? I quite allow that the Municipality makes strenuous efforts to deal with these matters ; but a fact that has been practically proved elsewhere, over and over again, is, that when a town covers more than a moderate area, efficient removal of night-soil and sullage by hand and carts must always be an impossibility.

*Statistics of benefits obtained by Sanitary Works.*

9. Happily, there is another fact established by experience, *viz.*, that the causes which produce normal high mortality are within the control of the local authorities ; and that by ensuring a sufficient supply of pure water, and by promptly removing the natural filthy productions of a large town, an abnormally high death-rate may be reduced, and made to approximate to normal proportions. It is because this fact has been so thoroughly established that the law in England gives large powers to the Local Government Board there, to enforce such action being taken by local authorities ; it is the reason why similar powers are given to the Local Government in this Presidency by the Municipal Act ; and it is the reason why large powers are given to the Municipal Boards themselves, to summarily deal with private rights and interests in cases affecting the public health.

10. The following are a few statistics illustrating the effect of water-supply and sewerage works on the public health :—

| Name of Town. | Population. | Cost of Water-supply. | Death-rate per 1,000. | |
|---|---|---|---|---|
| | | | Before. | After. |
| | | Pounds Sterling. | | |
| Chester ... ... ... ... | 39,569 | 74,816 | 30 | 23·3 |
| Gildersome ... ... ... | 4,000 | 2,000 | 27 | 16 |
| Hull ... ... ... ... | 149,000 | 215,000 | 31 | 16 |
| Manchester ... ... ... | 1,000,000 | 2,850,000 | 33 | 24·7 |

Effect of sewerage works :—

| Name of Town. | Death-rate per 1,000. | | Saving of Life per cent. | Reduction per cent. | |
|---|---|---|---|---|---|
| | Before. | After. | | Fevers. | Pulmonary Diseases. |
| Cardiff ... ... ... | 33·2 | 22·6 | 32 | 40 | 17 |
| Croydon ... ... ... | 23·7 | 18·6 | 22 | 64 | 17 |
| Macclesfield ... ... | 29·8 | 23·7 | 20 | 48 | 31 |
| Merthyr ... ... ... | 33·2 | 26·2 | 18 | 60 | 11 |
| Newport ... ... ... | 31·8 | 21·6 | 32 | 36 | 32 |
| Salisbury ... ... ... | 27·6 | 21·9 | 20 | 75 | 49 |

The average of the above works out to a saving of life of over 25 per cent. But assuming in your case that similar works only benefit you to the extent of 20 per cent., even this means an average reduction in the number of deaths of no less than 660 a year, and an average increase in the duration of life from 36, as it is at present, to 43 years. Of course all will not benefit equally, as other causes affect the death-rate also. Some will benefit more, some less ; but this is the *average*. And, moreover, the average number saved of cases of sickness of a more or less severe type will be nearly 14,000 a year, according to acknowledged statistics. Surely, such a result is worth paying for.

11. The experience of English towns has been reproduced in India; one striking instance of the effect of a pure water-supply being Burdwan, where the annual death-rate was 42 per 1,000 before the construction of the works. This rate was reduced to 20, only five years after ; and it was reported that the notorious Burdwan fever was gradually dying away.

12. In Calcutta the yearly death-rate now varies from 25 to 26 per 1,000 for those portions provided with water-supply and drainage works ; whilst in the suburbs, which are without those works, the rate is 44 to 69 ; and, as you are aware, that Municipality is now contemplating a very large expenditure to rectify this state of things. Excluding the suburbs, the cholera deaths there have been reduced from an annual average of 4,056 to 1,492.; and the deaths from fever have been reduced from 16,033 to 9,873 per annum.

13. In Cawnpore the yearly death-rate was just over 50 per 1,000 and attracted the attention of Parliament ; but, owing to the introduction of pure water, and to the completion of a portion of the drainage scheme, this rate is now largely reduced. In Ahmedabad the same thing has occurred ; and the people are themselves so convinced of the benefits of the sewerage works carried out in about one-fifth of the town, that they are eager to have the rest of the scheme completed, at a cost of about 16 lakhs. In Benares, and other towns all over India, the experience is invariably the same where the works have been carried out in accordance with the principles of modern sanitary science.

14. Naples (Italy) and Buenos Ayres (South America) are especially cases in point. In both, the people were accustomed to the filthiest habits, and were apparently without either ambition or desire to effect any improvement. The conditions of climate (as in India) foster neglect, and strongly incline to a policy of letting things alone ; and it requires a strong effort of will to combat such hindrances. They were, however, combated, and that effectually. The authorities found that trade was decreasing, and the population was diminishing ; both cities were swept, over and over again, by terrible epidemics of cholera, and people from other parts of the world, who had brought wealth and prosperity to these towns, were beginning to avoid them. Radical measures were, therefore, taken with regard to their water-supply and sewerage, and very large sums were spent in putting these in order, with the result that both places are now wholesome and pleasant to live in ; and the diminution in mortality, especially from infectious diseases, has been most remarkable. They are now the healthiest towns in their respective countries, and their prosperity is again increasing rapidly.

15. The necessity of intelligent co-ordination in water-supply and drainage is exemplified in the case of Bombay. There they have got a water-supply (of about 36 gallons per head of population ) very far in excess of any other town in India; and yet one hears constant complaints of its insufficiency and want of pressure. The only possible

explanation is that a very large proportion is allowed to run to waste, saturating the subsoil, and giving rise to an increase in the deaths from fevers and pulmonary diseases. The old sewers of Bombay are entirely opposed to the sanitary principles now established. They were carried out in the infancy of sanitary science, and the idea was to make them large enough to carry the enormous rainfall, as well as the sewage. Consequently, for two-thirds of each year the flow through them was altogether disproportionate to their size. Owing to the flatness of the area drained, the gradients of these sewers were far too small to give a self-cleansing velocity ; and for the greater part of the year they were simply cesspools, accumulating a foul and poisonous deposit. Modern investigation has settled that the drainage systems for sewage, and for rain-water, must be quite separate ; that the pipes and sewers for the former should be comparatively small, and laid with such a gradient as to ensure a self-cleansing velocity of 2 to 3 feet per second ; which will prevent the formation of any deposit, and ensure the sewage being delivered at the outfall in a very short time ; and these results are aided by frequent flushing from the heads of the various lines of sewers. The sewerage of Bombay is now being carried out on these lines, on the sectional system ; aided by Shone's ejectors, which enable the necessary sewer gradients to be obtained without excessive excavation. The sewerage of Colaba has been completed on this system, with very satisfactory results ; and I understand that progress is being made with the rest of the scheme. But until the saturation of the subsoil is prevented, or removed, the full benefit of their sewerage will not be felt.

*Poona Subsoil Water.*

16. In Poona you have also suffered from a rise in the subsoil water-level. In my opinion, this is due to two causes—(1) The existence of the three irrigation channels from the Karakwasla Canal, which carry a large amount of water to the lucerne fields and garden lands to the south-east of the town ; these lie immediately above the town, and the natural drainage from them must cross the town to the river. (2) The excess of the water-supply over the means of removing the sewage and sullage.

17. As regards the first, Government have been addressed on the matter ; and it is to be hoped that it will be found practicable to close these irrigation channels. It is probable that the filtration from them must be considerable ; as they irrigate perennially three hundred acres of lucerne grass, besides other garden crops.

18. As regards the second cause, the population of the City in 1891 was 115,000, and the yearly increase during the previous ten years was a little over 1,500. Your water-supply from the Katraj Tank and Karakwasla Canal is estimated at an average of 10 gallons per head, and from wells, and the three old aqueducts, an additional 5 gallons per head is obtained ; so that, normally, about two million gallons of water is now brought into the City every day. But no one can tell how much more water is brought in by the old aqueducts, and leaks into the subsoil

along their channels; in all probability, this is very considerable, judging by similar works elsewhere. Of this visible supply, however, the Omkareshwar Drain discharges only 180,000 gallons per day; and assuming that the Manik Nullah disposes of the same amount (which is very doubtful), over sixteen lakhs of gallons still remain. In the dry months a considerable portion of this evaporates; but if we assume that even one-third does so on the average throughout the year (which, I think, is a *very* outside allowance), there still remains over one million gallons per day; and this can only sink into the subsoil. This quantity is about equivalent to a continual flow of nearly two cubic feet per second, so that its power of surcharging the subsoil is evident. I think there can be no doubt that *this* is the chief cause of your subsoil water trouble; and the remedy is to remove this water (as sewage) by proper drains; and to substitute a system of iron pipes and services for your water-supply, which will enable you to close these old aqueducts and their cisterns, and the wells. Moreover, this liquid is contaminated sullage water, and must deleteriously affect the numerous wells and cisterns from which one-third of your water-supply is now obtained.

19. Some of you, I know, are of opinion that there are two other causes which have raised the subsoil water level, *viz.*:—(1) Leakage from the Karakwasla Canal between the Parbutti Tank and the Manik Nullah. (2) The heading back of the river water by the Jamsetjee Bund.

20. As regards the first of these points, the Executive Engineer for Irrigation informs me that the loss from leakage, between the Karakwasla Tank and Poona, averages one cubic foot per second per mile of canal; and that in the portion below the Parbutti Tank, the loss is much less than it is higher up; and that the leakage in the portion referred to is probably less than half a cubic foot a second, a large portion, if not the whole, of which must be carried off by the Nagzeri and Manik Nullahs.

21. As regards the second point, the levels show that any heading up by the Bund could not possibly have brought the subsoil water level to within many feet of its present level.

22. There is also an idea that the Jamsetjee Bund has caused the whole river bed above it to become silted up with a foul deposit, and that the Bund should be lowered, or abolished. Now experience in Southern India has shown that the silting effect of a Bund of this moderate height is practically nothing; as it only extends to a very short distance above it, owing to the "scooping" action of the flood-water as it rises to get over the Bund. The Executive Engineer, Poona District, carried out a series of soundings all over the river above the Bund, up to the Sungum, and experience of Southern India was exactly verified.

23. Of course, in the cold and hot weather, when the flow over the Bund is small, the daily pouring of even the three or three and-a-half lakhs of gallons of the City sewage into the river must foul the portion above the Bund, until the floods wash this comparatively stagnant water away; but this is all the more reason for dealing with the sewage of this large City in a more scientific way. If this sewage was not kept back by the Bund, it would pass on, and even more seriously contaminate the water-supply of villages and towns for many miles below Poona, which no community has a right to do; and the Local Government Board in England are especially strict in insisting on this not being done. The effect of the Bund, in checking the removal of the City sewage to some extent, simply brings home to you the evils that you might be inflicting on others.

*[redacted]sity of [redacted]r-supply [redacted] Drainage Poona.*

24. I trust that I have now said sufficient to convince you of the necessity for your taking up the two great questions of your water-supply and sewerage. In your case I think the second is the one to be taken up first, as it has now become too urgent to be delayed any longer; but the necessity of a pure water-supply should not be lost sight of, and should be taken up at the earliest possible period; and I would strongly urge that the preparation of a proper system of supply and distribution should be started *now*, so that when your sewerage scheme is carried out, or even earlier, everything may be ready for commencing the other great sanitary reform. Of course, some extra taxation will be necessary to provide the funds, but the undoubted benefits that will be gained will be well worth this; and I cannot think that you will be content to lag behind Ahmedabad in carrying out public works that will be so beneficial to yourselves and to your posterity. I will now take up the question of your sewerage, with which we are more immediately concerned at present.

*Present disposal of Sewage.*

25. The present system of disposing of sewage in Poona is, as you are aware, to cart the night-soil to a distance, where it is made into poudrette; and to cart a portion (probably not one-seventh) of the urine to the Manik Nullah, where it is discharged on to a platform, and causes a most offensive nuisance in the winding channel between this point and the river. These two items, however, are but a very small portion of your sewage, which approximates to two or three million gallons a day at present; the larger portion (which is principally sullage, but none the less offensive if allowed to accumulate) passes into your roadside drains, which are mostly made of ill-fitting stones, or bricks, the original mortar of which has long since been destroyed by the chemical action of this sullage. These drains are ordinarily square, which is the worst possible form. They have no regular fall, and no sufficiency of water to flush them; consequently, the flow must be sluggish, and most of the sullage must sink into the ground through the more or less open joints of the masonry; whilst some of it accumulates, and decomposes under the hot sun, with the baneful results that must be familiar to all of you. Even

these apologies for drains only exist in about one-third of the town; the rest has simply rough earthen gutters, more or less choked up. Part of the sullage (only 180,000 gallons a day) is eventually discharged by the Omkareshwar Drain into the river.

26. A considerable sum is realised by the sale of the poudrette for the cultivation of sugarcane; but the *net* result, allowing for the cost of collection, carting and manufacture, is a yearly *loss* to the Municipality of no less than Rs. 40,000 ; which is equivalent to the interest at 5 per cent., and the Sinking Fund for thirty years, on a capital sum of over six lakhs of rupees.

*Objections a System Open D*

27. Doubtless in this Municipality, as is almost invariably the case in this country, there are some who have a leaning to open drains for carrying off the sewage ; but I would point out to you that in numerous cases in this country this system *has* been tried, in some cases very extensively ; and in *every* case it has proved the failure and nuisance that, theoretically, might have been expected from it. Moreover, the larger the town, the greater is this failure and nuisance. Sholapur is an instance not very far from you, where surface drains have been extensively tried ; and they have found the obstruction to traffic, and the resulting plague of flies, so intolerable, that they are now going in for a scientific underground sewerage system. Cawnpore, Amritsar, Sukkur, Hyderabad (Sind), Dhulia, and many other places are further instances.

28. The objections to a system of roadside drains for sewage are :—

(1) The gutters present a large evaporating surface ; and after their contents are dried up, what remains is scattered by the wind.

(2) Their contents are liable to leak out, and to poison the ground on which the town is built, and to dangerously affect its water-supply.

(3) They are liable to be choked with rubbish, blown in by the wind, or washed in by the rain, or thrown in by the inhabitants ; and they require constant manual labour to keep them even moderately clean.

(4) Their gradients, as a rule, are not good, being made merely to conform to the fall of the roads ; and they are, therefore, not constructed on the "self-cleansing" principle.

(5) They are liable to overflow in times of heavy rain, and to deluge the ground in their vicinity with more or less diluted sewage, thus further poisoning the soil.

(6) Their appearance is objectionable, and they are often used as latrines.

(7) They occupy a large area of the roads that could be more beneficially used; and especially is this the case towards the tail of such a system, if the gutters are made proportionately larger to carry the increasing volume of sewage. The larger the town, the more serious is this objection. If the size is not increased progressively and proportionately, the drains overflow and cause a nuisance.

(8) Their length is double that of a central sewer; and, consequently, the volume of sewage that might flow with a self-cleansing velocity through one sewer, loses its flushing power by being distributed into two channels.

(9) The deeper open gutters are often dangerous to the public and to animals; and their near proximity to the habitations of the people, and to shops used for the sale of food, tends to render the former unhealthy and to taint the latter.

*Admission of Night-soil into Sewers.*

29. Some of you are doubtful of the advisability of turning night-soil into the sewers. I think, however, that you may safely accept the Report of the Royal Commission on Rivers Pollution in England on this point. There are many small towns in the north of England where the excreta is dealt with on the dry earth, or privy system, and does not find its way into the sewers; but in such cases the above Commissioners have shown conclusively that the sewage differs *very* slightly in composition and strength from that of water-closeted towns, where the whole of the excrement is admitted into the sewers. Ordinary town sewage is made up of bed-room and kitchen slops, soapsuds and dirty water from washing, drainage from slaughter-houses and stables, &c. In short, the greater part of the clean water supplied to a town returns ultimately to the sewers, charged with every conceivable pollution. Fresh sewage is generally comparatively free from smell; but when it has lain any length of time, as it does in badly laid sewers or drains, it becomes exceedingly offensive, even if not mixed with excreta, as you must often have experienced. The excreta forms an exceedingly small part (about ·2 per cent.) of the whole, and the velocity of the sewage in self-cleansing sewers soon breaks up such solid matters, so that they are delivered at the outfall in very different form, and before they have had time to decompose. The elements of decomposition, which make the sewage offensive, are practically as strong in the sewage from which excreta is excluded as where it is included. Moreover, if you exclude the excreta, you must continue your present method of collection and disposal, at a loss of Rs. 40,000 a year, representing a capital sum of over six lakhs of rupees; and the unsavoury and degrading nature of this method of collecting and disposing of night-soil in a large town, hardly requires to be pointed out.

30. That there should be a cautious advance in sanitary matters in this country is, I think, very advisable; but there are certain principles, such as sizes of drains, and rates of gradients suitable to certain discharges, &c., which are now finally established as being sufficient to remove sewage to the outfall before it can generate noxious gases. It is also now practically acknowledged in England that the biological system of purification in some form is the best; either on a sewage farm, where suitable land can be obtained; or by bacteria filter beds (which are practically a concentrated sewage farm), whether joined with a septic tank, or not. The septic tank will probably purify sewage enough to make it innocuous, but it requires the aërobic bacteria of the filters to form the nitrates, which give the effluent much of its value as a manure. Karachi has proved that a sewage farm in this country *can* be worked successfully in every way; and I have little doubt that the bacterial system of purification will be as successful, if not more so, out here as it is in England, where one town after another is adopting it; one of the latest being the large city of Manchester, under the advice of Mr. Baldwin Latham, who is probably the first sanitary expert of the day. *Principles of Modern Sewage disposal.*

31. Indian Municipalities are now passing through the stage that English Municipalities were passing through nearly thirty years ago, as is evident from the following extract from the Report of the Royal Sanitary Commission in 1871 on English Sanitation :— *Comparison of Indian and English Municipalities*

"Great is the *vis inertiæ* to be overcome, the repugnance to self "taxation, the practical distrust of science, and the number of persons "interested in offending against sanitary laws, even amongst those "who must constitute chiefly the local authorities to enforce them."

These words might have been written of many Indian Municipalities of the present day; but just as the English Boards have passed through this stage of doubt and hesitation, and have universally acknowledged the benefits to be obtained from water-supply and sewerage works, so will the Indian Boards emerge from this stage in a few years: and, as a matter of fact, in *every* case where a Board has carried out such works, the immediate result has been the full appreciation by the people of the benefits obtained. Ahmedabad is a case in point in this Presidency; and I trust that this Municipality will be equally ready to show the way to other less enlightened bodies.

32. Before I go further, permit me to explain to you the general arrangement of a scientific sectional drainage system. The pipes used are of glazed, impervious, stoneware, laid with cement joints, and vary from 6 or 7 inches to 15 or 18 inches in diameter. In this country it is impracticable to use much larger pipes, on account of the cost of carriage, and loss by breakage; where the volume of sewage requires larger accommodation, egg, or barrel-shaped masonry sewers, built with cement, are advisable. There seems to be an idea that sewers in this country *Principles of a Scientific Sectional Drainage System.*

cannot be laid so as to prevent the escape of sewage, or sewage gas; but, as the materials used are the same here as in Europe, there is no more likelihood of such escape here than there. The actual laying and jointing is merely a matter of careful supervision; and Rangoon, Benares, Cawnpore, Karachi, Ahmedabad and Colaba have effectually proved that the pipe-laying and house-connections *can* be done just as perfectly out here as in Europe. You may be quite sure that drainage systems would not have been made, or are being made, in every town of importance in Europe, America and Australia, if there was *now* any such probable danger. The idea seems to have arisen from the fact that the old sewers of Bombay and Calcutta did, undoubtedly, cause this danger; but I have already explained the cause of the faulty design of those old sewers, which is avoided in a drainage system designed according to the now acknowledged conditions of modern sanitary science. The only alternative is a system of open drains, and I think I have shown that they are impracticable for anything but comparatively small and uncrowded areas. These pipes, or sewers, are laid at such a slope that, when running half full, they will discharge at a velocity of at least 3 feet per second for Indian towns, so that they may be what is called "self-cleansing." This not only prevents deposits, but ensures the sewage being delivered at the outfall before it has time to decompose and generate noxious gases. In order to facilitate the cleaning, flushing and ventilating of these pipes, they are made to pass through manholes, which may be described as small masonry chambers with iron trap doors, placed 300 to 400 feet apart, and also at all changes of direction or gradient. The pipes are generally laid in the centre of the road, and at a minimum depth of 5 feet below the surface. At the summits of all the drains, automatic flushing tanks are placed, which will discharge at fixed intervals, two or three times a day, a proper quantity of water to keep the drains clean. At other points the manholes are provided with flushing gates, so that the chambers can be filled from the nearest hydrant, or even by the sewage itself, to obtain a rush of liquid down the drain. For low-lying portions of a town, the sewage must be lifted at the end of each such section into a higher section; and where the gradient (to ensure a self-cleansing velocity) causes an excessive depth of excavation, the sewage must also be lifted. Now you will readily understand that to have several small separate engines and pumps, all in duplicate, to lift the sewage at various points, would be inconvenient and expensive; and it is much better, and cheaper, to transmit the power to these various lifts from a central station, and so have only one set of machinery (of course, in duplicate) and one staff of men; and this is always done in such cases.

*The Hydraulic and Pneumatic Systems of raising Sewage.*

33. There are two methods of thus transmitting power from a central station, applicable to the sectional system of drainage. One is Latham's hydraulic, and the other is Shone's pneumatic system. Of these, I have no hesitation in recommending the latter; and I am supported in this by the opinions of the Hon'ble Mr. Doig, now Secretary

to Government, Public Works Department, who carried out an independent investigation into both systems; and also by the Municipal Engineers of Bombay, Karachi and Rangoon, where this system was adopted after prolonged and careful investigation, and has since been working to their entire satisfaction. I have myself visited nearly all the installations of both systems that were in existence about seven years ago, and in my opinion there can be no question about it. Since then, I believe, there have been no further installations of the hydraulic system, owing to the constant trouble experienced in the five or six towns where it had been adopted; whilst the pneumatic has been frequently adopted in new works, where the necessities of the case required it. In the hydraulic system, water, under a pressure of 600 to 800 lbs. per square inch, is used as the motive force; whilst in the pneumatic, air, at a pressure of 20 to 40 lbs. per square inch, is used; and, practically, it is found that there is no special difficulty in jointing the air mains, so as to ensure that the loss of pressure in any air main shall be less than one per cent. In the hydraulic system, pumps work in a sumph well, the valves give much trouble under the great pressure, and there is always more or less smell from the agitated sewage. In the pneumatic system, the sewage enters an air-tight iron chamber, in which there is a float which turns on the compressed air when the chamber is full, thus forcing the contents up the outlet pipe and closing the inlet valve. The float falls with the contents, and when the chamber is empty, the float turns off the compressed air and opens the exhaust; the outlet valve then closes, and the inlet opens and lets the sewage in again. The whole operation is sealed from the air; and even the exhaust air has no smell, as it is only in contact with the sewage for less than a minute; and everything that comes in at the inlet *must* go out at the outlet. The action is entirely automatic, and whether the flow of sewage is small or great, the motive force is only turned on when the float reaches the top of the chamber, and is at once turned off when it reaches the bottom. Thus, the filling of the chamber may take any time from one minute to one hour, according to the flow of sewage at different times; but the emptying is always done in less than a minute, sending a valuable and rapid flush along the rising main. In a recent letter from the Municipal Commissioner, Bombay, to the Corporation, regarding their drainage scheme, and Mr. Baldwin Latham's criticism of it, he says :— ..... "and the Shone system is to "be introduced in the sectional districts of the southern portion of the "island. I may add that I have been in communication with the Municipal authorities of Rangoon and Karachi, where the Shone system is "worked, and they have nothing but praise for it. In Colaba the system "has worked without a hitch, and no complaints of any kind have been "made regarding it. The Secretary of the Rangoon Municipality informs me that no ventilating shafts have been provided, and that smell "from the exhaust air (*i.e.*, of the ejectors), even when this is discharged "at ground level, is practically imperceptible." This last point was also noticed by Mr. Doig in his report to Government. You may perhaps

know, as stated by the Municipal Commissioner of Bombay (at the end of the letter from which I have quoted above), that Mr. Latham and Mr. Shone are rivals, and the statements made by either against the other's system must be received with caution. Mr. Latham has made many statements about the alleged deadly results of the exhaust air from the ejectors, especially as regards Henley-on-Thames and Rangoon, which have been repeatedly denied by the Municipal authorities concerned; and these denials were supported by health statistics, which proved the very reverse of Mr. B. Latham's allegations. I am not concerned with this, but I think I am bound to state it to you; and also that the opinion of unprejudiced observers is practically unanimously against Mr. Latham on this point. His eminent position as a sanitarian naturally causes any opinion of Mr. Latham's to be considered as valuable; but in this matter it would seem that private feelings have warped his usual sound judgment. I hope soon to be able to show you a working model of a Shone's ejector, from which you can see the simplicity and automatic certainty of its action.

*Health Statistics of Rangoon.*

34. The following statistics of the mortality returns of Rangoon, supplied by the Secretary to the Municipality, may be of interest; as this town has adopted the sectional system, with a large number of Shone's ejectors, owing to the flat nature of the area:—

| Year. | No. of Deaths. | | Death-rate per 1,000. | |
|---|---|---|---|---|
| | Sewered. | Unsewered. | Sewered. | Unsewered. |
| 1890 ... | 1,727 | 5,392 | 32·91 | 44·84 |
| 1891 ... | 1,679 | 5,009 | 31·24 | 40·41 |
| 1892 ... | 1,509 | 4,603 | 25·16 | 36·05 |
| 1893 ... | 1,628 | 4,573 | 26·31 | 34·78 |
| 1894 ... | 1,676 | 5,274 | 26·95 | 38·94 |
| 1895 ... | 1,381 | 4,400 | 21·23 | 31·32 |
| 1896 ... | 1,723 | 4,824 | 26·14 | 33·56 |

*Former Systems of Purification of Sewage and Disposal of Sludge.*

35. Before going into the details of the project, I propose to discuss the final purification and disposal of sewage. Until within the last few years many chemical processes have been advocated and tried, some of them successfully, as regards purification; but all have the great drawback of requiring strict attention to the details of the operation, and to the works themselves; but the greatest drawback of all is the expense and difficulty of dealing with the resultant sludge. Great expectations were at one time entertained of the manurial value of sludge; but it was found that the fertilisers in sludge (like the gold which is present in sea water) failed to repay the expense of making them available for use; for, after all, the value of the sludge is a very small part of that of the sewage; and the Royal Commission, which investigated this subject from 1858 to 1865, came to the conclusion, as the result of exhaustive experiments, that the sludge contained only one-eighth part of the value

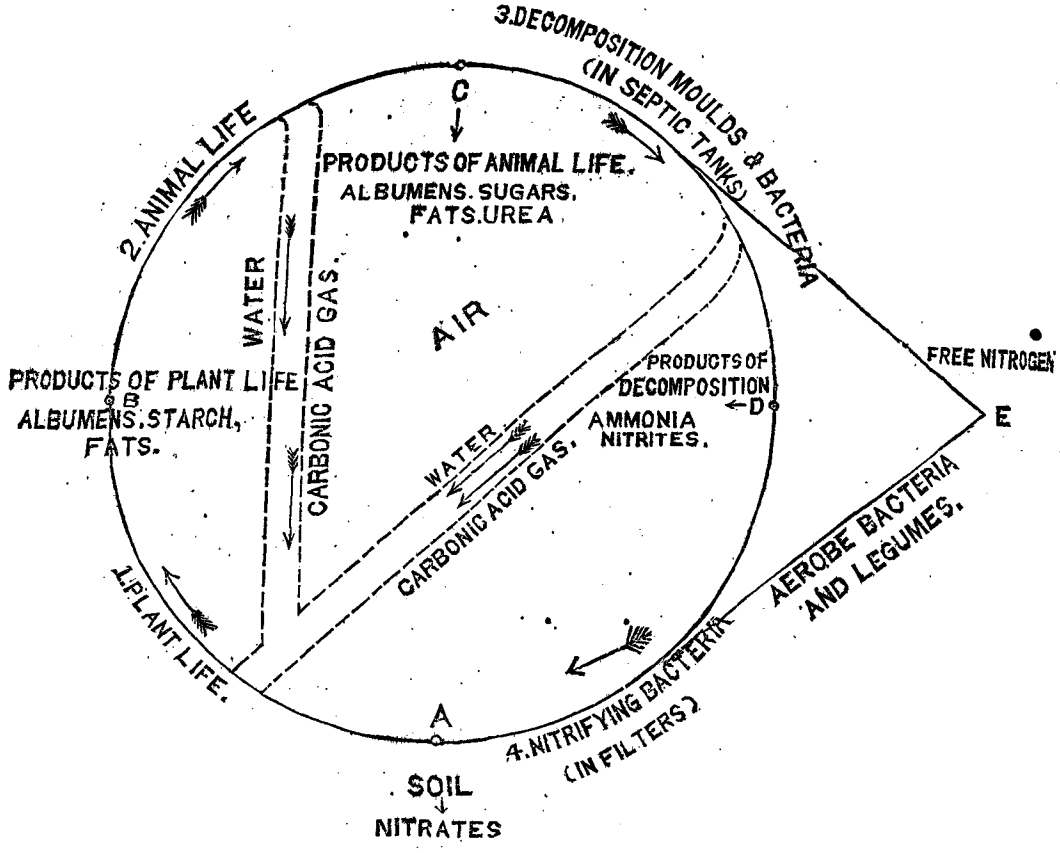
of sewage from an agricultural point of view. Except in a very few cases, sludge is now recognised as a material to be got rid of in the cheapest possible manner. The three largest towns in England, *viz.*, London, Manchester and Glasgow, now take their sludge in steam barges *out to* sea and sink it in deep water; and the cost of this for the one steamer of Manchester is about £7,000 a year, whilst London has six such steamers constantly at work.

*Biological Purification of Sewage.*

36. After the great number of valuable experiments carried out during the past ten or twelve years by the Massachusett's State Board of Health, and by Messrs. Dibdin, Scott-Moncrieff, Cameron and other eminent men, it may be safely assumed that the only satisfactory and *economical* way in which sewage can be *purified*, is to bring it under the influence of the micro-organisms, or "bacteria." Whenever or wherever there is decomposition of organic matter, whether it is of a plant, or tree, or animal body, the work is exclusively done by minute organisms. They are the most important, and almost the only agents of universal hygiene; they clear away the remains of all that has had life, more completely than even the dogs or jackals of this country; they protect the living against the dead—nay, more, if there are still living beings, if after the hundreds of centuries that the world has been inhabited, life continues, it is to them that we owe it. These bacteria, by a process comparable to that of digestion, are capable of breaking up all organic compound matters into their simple inorganic elements, by first converting them into nitrogen as ammonia, and then into nitrogen as nitrates and nitrites. Bacteria are present in all sewage, and are capable of indefinite multiplication under favourable circumstances; and it has been estimated that, *where everything was favourable*, sixteen millions would be the product of one bacterium in twenty-four hours. Fortunately for us, at least as regards the maleficent kinds, they have usually to struggle against adverse circumstances; and can only multiply with a sufficient supply of their own food and under certain conditions. As regards sewage bacteria, cold, or the presence of strong acids, alone limits their powers; and heat increases their numbers and power. One kind works in the dark and without air, and gets the oxygen necessary for their existence from the water of the sewage, liberating hydrogen, which is the other constituent of water, and they are called anaërobic; the other kind requires light, and air to supply oxygen, and are called aërobic. The former are utilised by a septic tank, which is made air-and-light-tight; the latter can be utilised by open air bacterial filter beds, or by land irrigation on suitable porous soil and of sufficient area. In no case has the effluent from bacterial filter beds given rise to any subsequent putrefaction; in fact, it further improves on keeping; and has actually been found to improve foul water, as in the case of the ship canal at Manchester. The effluent from a well managed and suitable sewage farm is equally innocuous, and for similar reasons, *viz.*, that the bacteria are able to work freely.

37. Now we may be quite sure that this natural and universal decomposition of all that has had life, serves a definite purpose of supreme importance in the economy of Nature. The materials which are suitable as food for the vegetable and animal world exist in limited quantities, and there is probably not enough of these materials in existence to maintain life on the earth for more than a year or two; so that, unless they were continually renewed, the world would soon become a desolate wilderness, without animals, or plants, or life of any kind whatever. But Nature uses the same materials over and over again. The food which we eat to-day has supported those who have lived before us, from the very beginning of life on the earth; and it will be prepared for our own use again and again by Nature, and will continue to support those who come after us. Perhaps the best way of illustrating the wonderful way in which Nature does this all-important duty is by a diagram, which shows how the chief ingredients of food are picked up from the soil and drunk in from the air by vegetation; and how this vegetation in turn comes to support the life of the animal world, including our own; and, finally, how the soil is replenished again.

*Nature's Food Cycle.*




38. We are all familiar with the first two operations of Nature's house-keeping; but we do not, perhaps, realise so clearly how carefully she collects the foul refuse which we throw aside, and builds it up again into vegetables and meat to carry us on for another year. We are apt to take it for granted, in a general sort of way, that the plants which grow in our fields and gardens, seize on the manure which comes from

animals, and build it up themselves into their stems and leaves. But, as a matter of fact, they can no more do this than we ourselves can live *directly* on the soil of the earth, or on the fertilising matters which it contains. Just as these must be taken up, and prepared for our use, by plant life, so must the refuse of animal-life be prepared for the plants before they can feed upon it; and this all-important work is performed by myriads of unpaid scavengers, whose existence was not even suspected until the last century. They are so tiny that it required the powerful microscopes of the present day to make them visible at all, and they are known to us as "bacteria," or more familiarly as "microbes." It was not until the middle of this century that the true nature of micro-organisms began to be worked out; and it is now no longer doubted that putrefaction and fermentation are the *results* of bacterial life, and not the cause of it; and that all bacteria are the offspring of pre-existing similar forms. Four hundred and forty species of bacteria are known at the present time, and these are classed and grouped in all sorts of ways; but the simplest method is to divide them up according to the changes they produce in the substances in which they grow. The four great divisions of this system are:—(1) Pigment bacteria, which produce colour stuff. (2) Ferment bacteria, which set up fermentation. (3) Putrefactive bacteria. (4) Pathogenic bacteria, or those which cause disease.

39. The products of animal life become first of all the prey of the decomposition moulds and bacteria, whereby they are converted into the various products of decomposition, such as ammonia salts and nitrites. These again are seized upon by other workers, which it is convenient to classify as "nitrifying bacteria," and converted by them into nitrates; which, I need hardly remind you, are among the most valuable of the artificial fertilisers of the day. Farmyard manure is largely converted into this form before it becomes available for plants. As I shall point out later, the decomposition moulds and bacteria are made use of in the septic tank to break down the polluting matter of sewage, and the work of purification is finally completed by the nitrifying bacteria in the filters. The continuous circular line in the diagram of "Nature's Food Cycle" shows the stages passed through by most of the nitrogen in our food; but certain other constituents do not follow quite so long a course. Thus, we breathe out from our lungs a great deal of carbonic acid gas and water vapour, and these are readily absorbed from the air by plants, without further change. The same constituents are also given off in large quantities during the process of decomposition, and do not require to be dealt with by the nitrifying bacteria before they can be utilised by plants.

*Sewage Farms.*

40. The droppings of animals are, for the most part, purified by bacteria on the surface of the earth; and this is what is aimed at in a sewage farm. Bacteria are found everywhere, and of various kinds; but those that we are now concerned with, live in the upper layers of the soil. When the sewage problem was first investigated, there were great

hopes that sewage farms would not only dispose of the sewage, but would bring in large profits; and the creed of many Sanitarians was—"The rainfall to the river and the sewage to the land." In all but a few cases, however, these hopes were not fulfilled, and the reason is not far to seek. Land is, undoubtedly, the *natural* receptacle for the refuse of the animal world; and if we were content to lead a primitive life, we might safely throw upon the soil the duty of dealing with our leavings. But it is not a natural state of things to concentrate the excrement of many thousands of people on a few acres of land; and it is still less a natural proceeding to also swamp such an area with hundreds of thousands of gallons of dirty water daily. It is because these things have frequently been done, that so many sewage farms are not a success; as Nature rebels against such treatment. The successful purification of sewage by land, day by day, throughout the year, requires a large area of suitable porous soil, and also careful and skilled management; both of which are expensive, and the former especially so in England. That sewage farms *can* be made a success in this country has been proved by Karachi, which is a true sewage farm, dealing with *all* the sewage, just as it comes to the outfall. Madras has also made a financial success of its huryali grass meadows; but there they do not use the whole of the sewage day by day, and the surplus is turned into the sea. That it can also be a failure here is proved by the Ahmedabad Farm, where everything was done that should not have been done, and *vice versa*; with the result that Nature rebelled, and the land became "sewage-sick" and choked with weeds; becoming, in fact, a nuisance, because the products of decomposition could not be utilised by the soil.

41. In 1892 Government appointed a Committee to consider the question of a sewage farm for Poona, and three sites were considered. Of these, I consider that No. 3 alone fulfils the conditions necessary for successful purification; and the Sanitary Commissioner, and Mr. Mollison, Deputy Director of Agriculture, entirely agree with me. This site lies between the fifth mile-stone on the Ahmednagar Road, and Wadgaum Sheri on the river. It has a porous, light soil, overlying moorum, and has a good slope to the river. It is true that the upper layer of soil is thin in places; but, with sewage irrigation, this does not so much matter, as the crops get their nutriment from the sewage; and the soil need only be considered as supporting their roots, and providing a suitable home for the bacteria. In Madras and Karachi the soil is practically sand.

42. The objections to this site were :—

(1) Great length of rising main. This is undoubted; but there is also the advantage that it removes the farm well away from the City and Cantonments; and the prevailing wind was ascertained to only blow from that direction for twenty-seven days in the year, on an average.

(2) The effluent will discharge into the river, opposite the Cavalry Lines and the village of Mundwa. This is also true : but in this country, owing to rapid evaporation, &c., it is probable that there will be little, if any, effluent ; and the effluent from a well-managed and suitable sewage farm is innocuous, as is shown by the Beddington Farm at Croydon, the effluent from which discharges into the small river Wandle, on which are valuable fishing rights, with numerous villas and houses, belonging to well-to-do people, on the banks, as well as around the farm, and yet no complaint has ever been made there. This farm consists of a thin layer of light soil overlying gravel.

(3) The sewage will have to be pumped to a considerable height. This is also true ; but it has the advantage of giving a good drainage slope to the river.

(4) Will interfere with the ground used for manœuvres by the troops. This, I think, is not very serious. The area is only about 1,300 acres, and the land immediately to the east is very broken. Also, it lies entirely to the south of the road ; and the troops, I believe, almost invariably work to the north of the road, where there is, practically, an unlimited area.

43. As regards the other two sites which were considered by the Committee, the soil consists, for the most part, of deep black soil, which is very retentive of moisture and similar to clay, and is most unsuitable for the successful maintenance of bacteria, as the air necessary for their existence could hardly penetrate, even the surface, when the land was soaked. The supposed advantage of having the canal water available to dilute the sewage might, perhaps, be considerable ; but Karachi has proved that a *strong* sewage *can* be utilised with a little care, the best, as well as the most paying crops being Indian corn and huryali grass. The land at these two sites would be far more expensive, and a much larger area would be required than on site No. 3 ; and, moreover, subsoil drainage would be essential, whilst it would not be required for No. 3 ; so that eventually the latter would be the cheapest, as well as the most suitable, for purifying the sewage.

44. The only successful way of utilising sewage on land is by "broad irrigation ;" which is done by running channels, as "carriers" for the sewage, along suitable lines, and laying out the land between them in long narrow plots, with a reasonable slope. Karachi at first started with small square plots (as Ahmedabad did), and failed ; but, on my suggestion, the Superintendent tried the other system, and since then the record of the farm has been an unbroken success ; and valuable data have been accumulated. If a sewage farm is adopted for Poona, an efficient Superintendent should be selected under the advice of Mr.

Mollison, Deputy Director of Agriculture, and sent to Karachi for a practical course of eight months, or a year. The land must then be properly laid out, stocked with a sufficient quantity of cattle and implements to work it, and buildings constructed to house these, and the staff and work-people. It is probable that agriculturists would take up a good deal of the sewage, as they are just beginning to do at Ahmedabad ; but it will take years to convince them of the benefit, as it has done there. Moreover, they will, of course, only take it when it suits them ; and the Municipality must be prepared to purify it at other times.

*[illegible]acteria [illegible]lters and [illegible]wage [illegible]rms.*

45. Alternative estimates for both a sewage farm, and for a septic tank and filter beds have been prepared. Personally I am in favour of the latter. Land treatment of sewage is practically the same as the bacterial filter treatment, as the latter is simply a development of the former. In each case the purification is effected by bacteria ; but in the former the result depends on human supervision, whilst in the latter it is automatic, and can be accurately ascertained beforehand ; as the filling and emptying of the different filters in succession is carried out by simple machinery, actuated by the flow of the sewage into, and the rise of the sewage in, the beds themselves ; and one man can easily attend to any number of such filter beds. The great principle is to fill the filter beds as quickly as possible, let them stand for two hours, and then empty and aërate them. The air follows the sewage, and there is seventeen times as much oxygen in a gallon of air as is required to oxydise the fluid, so that the cycle of operations can be repeated indefinitely ; and the beds improve enormously in working, as the bacteria multiply under each favourable conditions.

*Septic Tank.*

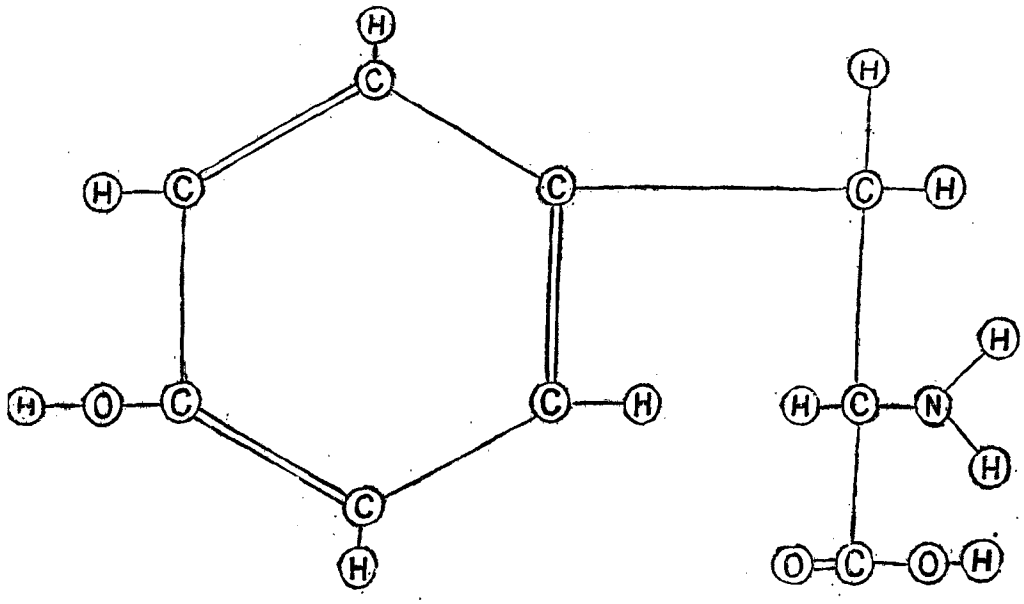
46. The septic tank, as I have said, is air-tight and light-tight. It consists of a series of long, narrow chambers, which have inspection manholes ; and these long chambers are covered by a concrete roof, and provided at the inlet end with grit chambers to arrest sand, &c., which the bacteria have no affinity for. These grit chambers are provided with manholes, to allow of periodical clearing out. The sewage enters the tank by inlets, at a depth of about 3 feet below the surface. The object of this is threefold. In the first place, the leathery scum which forms on the surface in the tank (to which I shall refer presently) is undisturbed. In the second place, no air can enter with the sewage ; and, lastly, the gases generated in the tank cannot escape back into the sewer. The flow through the tank is continuous, and the effluent passes off at practically the same level as the sewage enters. The tank is calculated to hold more than one day's flow of sewage, *i.e.*, the sewage that enters at 10 o'clock one morning cannot pass out before 10 o'clock next morning ; so that the rate of flow is exceedingly slow, and the solid matter present in the sewage has plenty of time to settle to the bottom, or to rise to the surface, according as it is heavier, or lighter than the water in the tank. The effluent is drawn off at the other end, between the scum on the top and the heavy deposit at the bottom, by

a cast-iron pipe running the full width of the chamber, and about $2\frac{1}{4}$ feet below the surface ; in the lower side of this pipe there is a continuous slot, or opening, about half an inch wide, through which the effluent passes in a thin sheet, the whole width of the chamber, with the least possible disturbance of the contents of the latter ; or the pipe can be fitted with open tees at close intervals.

47. So far, only the solids have been arrested, and the sludge still remains ; but sewage contains within itself the seeds of its own destruction. Under the conditions provided in the septic tank, the bacteria attack the impurities, and gradually resolve them into simpler forms. There are, as I have said, many hundreds of species of these tiny scavengers (human fœces alone contain several scores), and each kind does a separate portion of the work. The leathery scum which soon forms on the surface is full of bacteria, and forms a sort of yeast which sets up the fermentation or decomposition by which the solid matter is eventually broken down. These bacteria are the sworn foes of the disease germs, and it is by their means that the ravages of disease are restricted. In the septic tank, and again in the filters, any pathogenic bacteria which the sewage may contain are systematically exposed to the attack of their deadly enemies, first of one kind and then of another ; and the system thus furnishes an effective safeguard against the propagation of disease by the sewage with which it deals.

48. It must not, however, be supposed that this decomposition takes place instantaneously ; on the contrary, it may take days, or even weeks, to break down *some* of the material. One squad of microbes attacks a piece of solid matter, and the change they bring about is perhaps imperceptible. Another group takes up the work where the others leave it off ; and so, little by little, the solid particle crumbles away and disappears. Sewage is of an exceedingly complex nature, and consists of hundreds of organic compounds, many of a very complex composition. The atoms comprising each molecule are, however, never thrown together haphazard, but are always grouped according to certain well understood laws ; consequently, it is very difficult to take away any single atom from the components of a molecule without breaking down the latter. Children often amuse themselves by building houses of cards ; it only requires a steady hand to raise a considerable construction, but it is very difficult to remove even the top card without shaking down the whole structure ; and this result is certain if you remove a card from the bottom. Similarly, the removal of even two or three atoms of a molecule generally breaks down the substance into a number of simpler bodies altogether unlike the original compound ; and this is especially the case in the septic tank, where the decomposition takes place in the absence of air. The result of these operations is that we get an effluent practically free from solid matter, and showing a marked purification even as regards impurities.

49. This latter result may at first sight seem surprising when it is remembered that the solid matter has, to a great extent, been thrown into solution ; but let us consider what actually becomes of it.



This formidable-looking diagram represents the molecules forming one of the atoms of the simpler substances formed by the process of digestion. C stands for carbon, H for hydrogen, O for oxygen, and N for nitrogen, which constitute by far the larger part of all organic compounds. When this atom is decomposed, the oxygen will be snapped up by some of the carbons, forming carbonic acid gas ($CO_2$). A little of the oxygen may combine with some of the hydrogen to form water ($HO_2$). The nitrogen will probably take some hydrogen, forming ammonia ($NH_3$). Some of the carbons will take some of the hydrogen, and form " methane," or marsh gas ($CH_4$); and possibly some free hydrogen may remain. Now of all these products of the decomposition, only ammonia would, ordinarily, be considered as " polluting matter " by an analyst ; and even this will generally suffer further decomposition, so that the quantity remaining in the effluent will be less than was originally present in the sewage. Thus, the whole of the above organic compound would be broken up into water and certain inoffensive gases, leaving not a trace of solid matter. The whole of the solids, however, will not, as a rule, be so completely soluble ; so that there will generally remain a small amount of residue, or "ash," just as there would be if fire had been used ; but the experience of the Exeter Tank shows that this only accumulates at a rate of about one foot in depth in a year. An organic compound is a conglomeration of an infinite number of inconceivably small atoms, each of similar constituents ; and the destruction of the whole body is simply a matter of the continued destruction of the component atoms, as above.

50. The falling flakes, which eventually become ash, drag the organic matter in suspension down to the bottom of the tank ; here a fresh action sets in, and a gaseous bubble is formed, by which each

particle is again carried up to the underside of the leathery crust, or scum. The bubble gradually squeezes through this crust, and bursts under the dome of the tank; and the particle, having lost its gaseous support, again falls to the bottom; and this process is repeated until nothing remains beyond mineral ash, on which bacteria cannot feed.

*Resulting Gas as an Illuminant.*

51. From this description you will see that amongst the final products of decomposition are methane, or marsh gas, and hydrogen, both of which are very inflammable. The flame, although a very hot one, is not luminous in itself, but becomes so by the aid of an incandescent mantle; the works at Exeter are thus lighted with the gases produced in the tank, and the same course can be followed here.

*Bacterial Filters.*

52. During the *preliminary* decomposition, it is important to exclude air as far as possible; but when the solids have been brought into solution, it becomes necessary to oxidise them. The tank effluent is, therefore, passed through an aërator, over the edge of which it falls in a thin film, thereby picking up a certain amount of air; and the work of oxidisation is completed in the filters, which are usually filled with furnace clinker. The tank effluent is admitted to each filter in turn, through a valve, and distributed over the surface by a channel stretching diagonally across it. The filtered effluent is collected, in the usual way, by drains laid on the floor, and then taken to the discharge outlet.

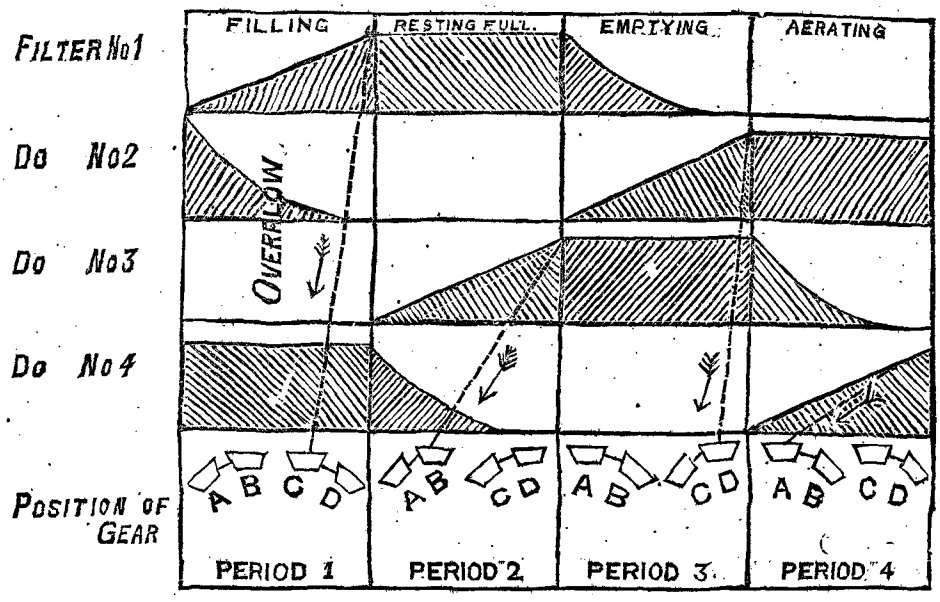
53. If it is attempted to purify sewage by simply passing it *through* a filter, it is difficult to ensure the uniform distribution of the liquid over the whole area; some parts get more work than they can do, and others do less than their proper share. Moreover, the filtration of a sewage effluent must be intermittent; otherwise there could be no real purification, and the filter would soon become very foul. The reason for this is, that the work of the filter consists in oxidising the polluting matter in the effluent. This duty, like the preliminary liquefaction in the tank, is the work of the bacteria; but the workers in the filter (unlike those in the tank, which only thrive in the absence of air) require a plentiful supply of air to allow them to perform their functions. In a healthy filter the bacteria are found in thin films covering the particles of the filtering materials. To ensure this, each filter is filled in turn; then allowed to rest full for a certain time; and, finally, left to drain, and aërate; about two hours is the time usually allowed for each operation, so that each filter can be used three times in the twenty-four hours.

54. You will remember that one of the chief products of the decomposition of the sewage in the tank was ammonia ($NH_3$), a compound of one atom of nitrogen with three of hydrogen. The oxidisation of this compound into nitric acid ($HNO_3$) is accomplished by means of the nitrifying bacteria, already referred to in connection with the diagram of "Nature's Food Cycle." For the purposes of sewage purification, an aërated bacterial filter is thus virtually the equivalent of land, concentrated into a small area and brought under control.

*Automatic Working of Filters.*

55. The automatic filling, resting, emptying, and aërating of each filter in turn, at Exeter, is done by very simple apparatus, which was originally designed merely as a labour-saving device; but it soon became apparent that the chief value lay in the absolute regularity with which it did its work, which enables the filters to do their full work without deteriorating—a result that could not be always expected from manual labour. The filters are grouped together in pairs, and the supply and discharge valves of the filters of each pair are suspended from the opposite ends of two levers fixed on a rocking shaft, which also carries two other levers, with a copper bucket at the end of each. As soon as a filter of one pair is full, a small quantity of the filtered effluent from its discharging well overflows by a pipe into the bucket of the corresponding filter of the adjoining pair, which has been resting full; when this bucket is full, it will descend, turning the shaft in its bearings; thus opening the discharge valve of the filter that has been resting full, and opening the inlet valve of the other filter of this pair which has been aërating. At the same time the inlet valve of the filter that has just been filled is closed. This diagram may possibly put this more clearly.

*Diagram showing Cycle of Filters.*




During the first period shown here, filter No. 1 is filling, No. 2 is emptying, No. 3 is aërating, and No. 4 is resting full. When No. 1 is filled, the overflow of the filtered effluent from the discharge well of this filter passes by a pipe into the bucket C; and when this bucket is full, its weight causes it to descend, rocking the shaft on which the levers supporting the buckets C and D are fixed. This shaft also works the levers from which the inlet and discharge valves are suspended, and the inlet valve of filter No. 1 is closed, the inlet valve of No. 3 is opened, and the discharge valve of No. 4 is opened. Thus, during the second period No. 1 is resting full, No. 2 is aërating, No. 3 is filling, and No. 4

is emptying. At the end of this period, when No. 3 is filled, its overflow passes by a pipe into the bucket B, closing the inlet valve of No. 3, opening the inlet valve of No. 2, and opening the discharging valve of No. 1. At the end of the third period, filter No. 2 overflows into the bucket D, closing the inlet valve of No. 2, opening the inlet valve of No. 4, and opening the discharging valve of No. 3. At the end of the fourth period, filter No. 4 overflows into the bucket A, closing the inlet valve of No. 4, opening the inlet valve of No. 1, and opening the discharging valve of No. 2. This cycle goes on indefinitely as long as the flow continues ; and practically the only supervision required is to see that the bearings of the rocking shafts are lubricated, and that the valves and their rods work freely.

*Biologic Installat in Engla*

56. Many installations of this system have been carried out in England in the last three or four years, and always with unvarying success. Amongst the later installations have been the large towns of Manchester, under the advice of Mr. Baldwin Latham, and Leeds, under the advice of Mr. Mansergh, who are two sanitarians of world-wide celebrity. The sewage of Leeds is exceedingly foul from manufacturing refuse, and exhaustive experiments with it were first made before the system was adopted. Yeovil is also one of the later installations, and has an exceedingly "strong" sewage, which is very variable in its constituents, containing at different times the washings from breweries and slaughter-houses, and the waste liquors from several leather dressing yards, which are charged with dye-stuff, hydrochloric acid and arsenic ; and the difficulty of dealing with it was accentuated by the fact that the various chemical discharges came down in sudden rushes at different times in the day. Taken singly, they would probably ruin the filters ; and the successful results obtained with such sewage are largely due to the action of the tank in blending together the various conflicting liquids which came down the sewers from time to time, and sending on to the filters an effluent of approximately uniform quality. The preliminary test that the septic tank and filters have been put to there for over two years was, therefore, a very severe one ; and although samples of the effluent were regularly and carefully taken throughout that period, and analysed by eminent chemists, in not one case was the analytical report unfavourable. Exactly the same results have been got elsewhere ; and the effluent is uniformly found to be of high quality and perfectly inoffensive, and remains so when kept for any length of time. This has been the case under all conditions of weather and temperature ; and the effluent is pronounced fit to be turned into any stream without injury to it, and may even improve it. During the construction of the permanent works at Exeter, the labourers engaged on this work habitually drank the effluent from the experimental tank and filters, in preference to the river water. The Rivers Committee of the Manchester City Council have a very practical way of determining the purity, or otherwise, of an effluent. They keep it in a stoppered bottle at a constant temperature for some five or six days ; and at the end of this time if the effluent is not

a good one it develops an offensive smell. Water from the Manchester Ship Canal, for instance, becomes putrid when kept in this way. This Committee has given most striking testimony to the purity of the Exeter effluent, as the result of the exhaustive tests carried out by them.

*[redacted]urial [redacted]ue and [redacted]olicability Effluent.*

57. As I have already explained, this final effluent is very rich in nitrates, which is one of the most valuable constituents of any manure, or fertiliser. As the effluent is without smell, and does not undergo secondary decomposition, it is in every way a very valuable irrigating material; and can be applied to land, just as water is, without any of the difficulty experienced in successfully applying raw sewage to crops. As it is also innocuous as a potable water, it can either be turned into the river, or utilised on land; and its inoffensive nature will allow of its being utilised in the neighbourhood of a town, without causing any more nuisance than ordinary water would. At Exeter there are several houses, many of them high class ones, within 200 or 300 yards of the works; and at Yeovil there is a large factory immediately adjoining the works; but the owners have in no case experienced any nuisance therefrom.

*Site for Septic Tank and Filters.*

58. I propose, therefore, to locate the septic tank and filter beds on the site of the present plague camp, between the railway and the river. This land can probably be got at a reasonable cost, and is conveniently situated in every way, both as regards the natural outfall of the town drainage, and also for disposing of the effluent into the river; unless it is utilised, as I think it should be, for irrigation. I also propose to put the engine-house and air-compressor plant at the same site, so that the works can be lit by the gas evolved from the tank, as is done at Exeter. If the Municipality decide to utilise the effluent for irrigation (which, I think, ought certainly to be done), the Worthington engines and pumps, and the reservoir for the night effluent, can also be located at this site, as well as the buildings for the engineers, firemen and stokers.

*Profitable Utilisation of Effluent.*

59. For profitably utilising the effluent, probably the best way will be to pump it to where the Sholapore Road crosses the Southern Maratha Railway near Hadapsar, and thence take it by a small channel to the adjoining land, for sugarcane. A branch can be taken from the rising main, across the canal near the aqueduct in the twelfth mile, and the land to the north of the canal utilised for valuable fodder crops during the monsoon, when the effluent will not be much wanted for sugarcane. As this land is within the prohibited limit for sugarcane, it can be got at a reasonable price, and it is commanded by the canal. As the effluent will not require dilution for sugarcane, the less valuable land to the south of the canal, and outside the prohibited limit, can be utilised for this valuable crop.* Mr. Mollison states that, according to his experiments at Manjhri, two million gallons a day will quite suffice for 500 acres of sugarcane and 300 acres of monsoon fodder crops; as a depth of

* NOTE.—*This has since been altered, in accordance with Mr. Mollison's final suggestions; and the whole of the effluent will be taken to near the sixth milestone of the Sholapore road.*

50 inches of water is more than enough for sugarcane during the year. For this, a storage tank, of about 200,000 cubic feet capacity, will be required for the storage of the effluent from the night sewage, and to provide a reserve for the pumps to draw on ; also, a duplicate set of Worthington engines, and a rising main of suitable size. A similar storage tank would probably be necessary at the end of the rising main. This, however, is a matter to be settled hereafter. In any case, you may be quite sure that the cultivators will require an object lesson to satisfy themselves as to the value of the effluent before they will adopt it ; and it would probably pay you better to utilise the effluent on a farm of your own, from the beginning.

*Conditions to be fulfilled by an Effluent.*

60. In considering the purification of sewage, the minimum conditions which must be fulfilled by an effluent are :—

(1) It must contain practically no solids in suspension.

(2) It must not contain in solution a quantity of organic matter sufficient to seriously rob of its oxygen any stream into which it is discharged.

(3) The organic matter which it contains must be in such a condition as to yield readily to the natural purifying influences exerted upon it.

(4) It must not be liable to putrefaction, or secondary decomposition. This is most important.

(5) It must contain nothing inimical to microbial growth and activity ; in other words, it must not be sterilized, or treated with antiseptics.

(6) It must not contain pathogenic (disease) organisms.

*Analysis of Septic Tank Effluent.*

61. Now the septic tank and bacteria filters fulfil more than all these conditions. Messrs. Pearmain and Moor, who are well-known members of the Society of Public Analysts, investigated the septic tank system at Exeter for the Manchester Corporation ; and, amongst other things, they analysed six samples each of the raw sewage, tank effluent, and filter effluent, on six different days, with the following average result in grains per gallon :—

| — | Raw Sewage. | Tank Effluent. | Filter Effluent. |
|---|---|---|---|
| Total solids ... | 57·0 | 37·7 | 31·5 |
| Mineral matter | 28·3 | 24·5 | 25· |
| Loss on ignition | 29·0 | 13·2 | 6·6 |
| Chlorine | 6·05 | 4·6 | 4·5 |
| Hardness | 8·0 | 9·0 | 10·2 |
| Nitrites | none | none | none |
| Nitrates | traces | traces | ·91 |
| Saline ammonia | 4·4 | 2·82 | 1·16 |
| Albuminoid ammonia | ·74 | ·47 | ·11 |
| Oxygen absorbed | 4·3 | 1·4 | ·33 |

The next table shows the percentage purification produced by the septic tank process, as worked out by different observers, and judged by the removal of albuminoid ammonia and oxidisable matter :—

| Authority. | Albuminoid Ammonia. | Oxidisable Matter. |
|---|---|---|
| Dibdin and Thudichum ... ... ... ... | 63·2 | 80·9 |
| Dupré ... ... ... ... ... ... | 84·9 | 88·3 |
| Pearmain and Moor ... ... ... ... ... | 80·0 | 90·0 |
| Perkins ... ... ... ... ... ... | 64·4 | 78·7 |
| Rideal ... ... ... ... ... ... | 77·0 | 82·0 |

[redacted]*riment*
*tta.*

62. Major Melville, R. A. M. C., carried out last year a rough experiment with a small septic tank and filter at Quetta. The tank and filter were each only 3 feet square and 1½ feet deep ; but even so, the result was so satisfactory that it is proposed to deal with the whole of their sewage properly, on this system. The mixture used at first was, equal parts of (liquid and solid) night-soil, and slop water. To bring this into the condition that your sewage will be, with even your present water-supply of 15 gallons per head, an amount of water, twenty-five to thirty times the bulk of this concentrated sewage, should have been added to it. After twenty-four hours in the tank the effluent was run into the filter, left to stand there for two to three hours, and then run off. Chemical examinations were made of the tank and filter effluents from time to time ; but, for various reasons, this was practically limited to ascertaining the amount of oxidisable matters. Owing to the extremely concentrated nature of the sewage, the oxidisable matters in the mixture averaged 175 grains per gallon ; as against four to seven grains, which is the average in England ; *i.e.*, to bring the Quetta mixture to the condition of average English sewage, an addition of thirty to forty times its bulk of water should have been added, the water-supply of English towns being at least 25 gallons per head. Owing to the concentrated nature of the sewage, the oxidisable matter in the tank at Quetta increased during the first twelve hours, instead of showing a slight decrease ; but then it gradually, but slightly, decreased ; and when diluted with only ten times its bulk of water, it showed a decrease of 20 per cent. in twenty-four hours, as against the average of 30 per cent. in the Exeter experiments ; thus showing in a striking manner how the dissolved oxygen in the water of ordinary diluted sewage enables the anaërobic bacteria in the tank to work more energetically. In the Quetta *filter* there was a considerable decrease in the oxidisable matter of the concentrated mixture, amounting to 66 per cent. ; and when the mixture was left in the filter for a longer period, this decrease was 95 per cent.

63. It must be remembered that in a very small experiment like this, not only was the sewage extremely concentrated, but the solid matter (fœces) was not broken up, as it would have been by a rapid passage

through the sewers ; and, consequently, the micro-organisms could not attack it so readily. With a proper system, and a larger tank and corresponding filters, the result must obviously be much better. Major Melville considers that for *their* purposes it will be sufficient to dilute their concentrated mixture with four times its bulk of water, giving about 35 grains of oxidisable matter per gallon of mixture. Your sewage will probably average about only six grains of oxidisable matter per gallon of sewage. He proposes (in their permanent scheme) to leave the mixture in the tank for twenty-four hours, and in the filter for six hours ; and to allow two hours for filling, and the same for emptying the filter. As the dilution of your sewage will be much greater, the ordinary two hours' cycle for each filter operation will suffice. You will understand that as the Quetta sewage has to be removed by hand and cart, it is important to limit its dilution. Major Melville says :—"The dilution of the sewage would be "1 to 2½ roughly ; counting the slop water as sewage, as it really is; the "process is absolutely safe and rapid ; and once the tank and filters are "built, there is no further expense ; as when the system is started, its "carrying out is largely mechanical and automatic."

*Experiment in Bengal.*

64. The Sanitary Engineer, Bengal, has recently put up a septic tank and filters in the Presidency Jail, to deal with the night-soil and urine of 150 men. Three gallons of water is added to each stool; which is the volume of the syphon-flushing tanks proposed for your privies. He says :— "This is strong as compared with English sewage, but so "far I am quite satisfied with the results." He has also been carrying out experiments in several other places on urine, with filters only, but is satisfied :—"that no purification can be effected unless it is allowed "to rest for some hours in a closed and almost air-tight vessel, or else "by using double filters."

*Experiment at Poona.*

65. You are aware that an experimental septic tank and filters have also been working here from the beginning of May, and I think that there can be no doubt as to the satisfactory results obtained. I had no fear as to the anaërobic bacteria in the tank, as they flourish in a damp heat ; but no one could say for certain that the aërobic bacteria in the filters would find a hot weather sun suitable to them. Of course, in a larger installation the results would be much better ; as in a large tank the sewage would be able to mix better, and the solid matter would be more broken up.

*Probable Value of Effluent.*

66. In conjunction with this experiment, Mr. Mollison has kindly carried out careful experiments as to the manurial value of this effluent, as compared, respectively, with poudrette, and farm-yard manure. The results obtained, as well as the analysis of samples taken from time to time, will be given hereafter as an appendix. Mr. Mollison states that for an acre of sugarcane near Poona, the cultivator pays Rs. 50 for the canal water and from Rs. 150 to Rs. 200 for poudrette, and that the crop is worth about Rs. 500 or more. He also considers that 2,000,000 gallons daily of effluent would suffice for irrigating about 500 acres of

sugarcane. If the manurial value of the effluent is, as anticipated, equal to that of canal water and poudrette, your Municipality ought to have no difficulty in the future in financing *all* your wants; whether you take up land yourselves, or sell the effluent as the canal water is sold, *i.e.*, at so much per acre per crop. During the monsoon months the effluent would suffice for more than the above area; and Mr. Mollison thinks that a Municipal Farm should comprise at least 800 to 1,000 acres, and grow fodder crops on the surplus effluent in the monsoon; moreover, this would allow of the sugarcane area being changed each year. To profitably utilise the effluent in the monsoon, he considers that light land is essential, as the effluent could only be profitably utilised on black soil during the fair weather.

*[redacted]gical ems.*

67. In England there are several other systems of bacterial purification in use, such as those of Dibdin (which was the original one), Garfield, Scott-Moncrieff, and Ducat. In Dibdin's, two filters, or even three, are used; the first being filled with coarse material, and the others with finer stuff. In Garfield's filter the sewage passes upwards through graduated layers of coal. In Scott-Moncrieff's filter the sewage also passes upwards, through a grating, supporting the requisite depth of flints. In Ducat's filter the filtering material is aërated by pipes, and the depth of this material varies according to the quality of the sewage. Secondary filters are often used in each case, to get a high degree of purification. A royalty is charged for all of these, except the first, just as the Septic Tank Syndicate charge for theirs; and the purification obtained in *England* is about the same for all; but I cannot help thinking that the *preliminary* decomposition of the sewage in *this* country could not be effected in an *open* filter without causing more or less of a nuisance; this would necessitate the works being placed at a distance, entailing a large length of expensive main sewer; and possibly pumping at the end, as all these systems require a much greater "head" to work them than the Septic Tank does; so that the cost of even Dibdin's system would probably not be less than the Septic Tank and Filters, especially as more than four times the area would be required for Dibdin's filters. An experiment with these filters will probably be carried out shortly by the Agricultural Department.

*Leading Features of Poona Drainage Scheme.*

68. I will now proceed to explain the leading features of your sewerage project, and trust I have not wearied you with these preliminary matters; but the biological disposal of sewage is of comparatively modern origin, and many people have only vague ideas about it; and the very mention of microbes, or bacteria, is apt to conjure up visions of disease. The statements made, and explanations given, have been gathered from acknowledged authorities on the subject, such as Dr. Clowes, now Chemist to the London County Council; Mr. Dibdin, who was his predecessor; Dr. Rideal, Mr. Martin, Mr. Cameron and other eminent scientists; and they may safely be accepted as representing the latest developments of sanitary science, about which the unanimity of

opinion is wonderful. I hope you are now convinced that there are both beneficent, as well as maleficent, bacteria; and that usually the former far outnumber the latter, and are our very good friends and servants. Also, that the Sectional System of Drainage, aided by Shone's Ejectors where necessary to get a sufficient gradient without too deep excavation, is both sanitary and successful; that sewers and house-connections *can* be made gas and water-tight in this country as elsewhere; and that the admission of night-soil into a properly designed Drainage System has no bad effects of any kind.

69. On the 45 sheets of Plans of the City, drawn to a scale of 50 feet to an inch, are shown the lines and diameters of the gravitating sewers, and of the sewage and air mains; and the positions of ejector stations; automatic flushing tanks, for both sewage, and water; and manholes, both ordinary, and with flushing sluices; also, the reduced levels of ground, and of inverts of sewers; and the boundaries of the different sewerage areas. The ground levels are taken from Colonel Ducat's scheme; and although these are not in detail for each street, yet the contours are a fairly accurate guide. Sections of each line of sewer have also been drawn, to a scale of 20 feet to an inch vertical, and 200 feet to an inch horizontal. A reference sheet illustrates the above 45 sheets; and also the General Plan of the City (sheet No. 1), on a scale of 200 feet to an inch.

*Quantity of Sewage to be dealt with.*

70. Regarding the quantity of sewage to be dealt with, this may be taken as practically the amount of your water-supply. The latter is, at present, 15 gallons per head (5 from wells and 10 from other sources); but, for the reasons that I have endeavoured to impress upon you, I trust you will see the necessity of soon having an improved and sanitary water-supply scheme; and this would speedily raise the consumption, as has been proved by Ahmedabad; especially if house-connections for water are freely allowed, as they safely can be when you have an efficient drainage system. I have, therefore, calculated for 20 gallons per head per diem for your sewage; and this amount was also taken by Mr. Doig in his rough calculation for such a scheme in 1892. The calculation for population is based on the census of 1891, allowing for the average yearly increase of the preceding years, up to the year 1931; as your drainage scheme cannot be in operation before 1902. The sewers are, as usual, calculated to carry the above volumes when running half full with a self-cleansing velocity. As the velocity remains the same, whether the sewers are running half full or more, up to full bore, it follows that these sewers will allow of an increase of water-supply up to 40 gallons per head, or for double the estimated population; or for any combination of these two increases, within the *joint* maximum limit; and they will be equally efficient for any smaller volume, so that the scheme will suffice, practically for any reasonable limit of time; the only additions ever likely to be necessary being to the cast iron syphons, and Septic Tank and Filter Beds, which can easily be carried out.

71. Table A gives the estimate of population on the above basis, and also according to the present density of population; and on these figures the calculations as to the sizes of the gravitating, or collecting sewers, and of the quantites of sewage to be dealt with at various points, are based.

TABLE A.

| Peth Letter. | Population in 1891. | Estimated increase 1891-1901. | Population in 1901. | Estimated increase 1901-1931. | Population in 1931. |
|---|---|---|---|---|---|
| A ... ... ... | 7,661 | 1,500 | 9,161 | 5,000 | 12,661 |
| B ... ... ... | 7,352 | 1,300 | 8,652 | 4,300 | 11,652 |
| C ... ... ... | 4,078 | 200 | 4,278 | 894 | 4,972 |
| D ... ... ... | 1,368 | 200 | 1,568 | 1,200 | 2,568 |
| E ... ... ... | 4,828 | 800 | 5,628 | 2,800 | 7,628 |
| F ... ... ... | 4,516 | 700 | 5,216 | 3,200 | 7,716 |
| G ... ... ... | 2,558 | 250 | 2,808 | 1,750 | 4,308 |
| H ... ... ... | 13,534 | 500 | 14,034 | 1,966 | 15,500 |
| I ... ... ... | 10,694 | 300 | 10,964 | 900 | 11,594 |
| J ... ... ... | 5,237 | 500 | 5,737 | 900 | 6,137 |
| K ... ... ... | 5,425 | 250 | 5,675 | 2,250 | 7,675 |
| L ... ... ... | 1,153 | 500 | 1,653 | 3,000 | 4,153 |
| M ... ... ... | 16,359 | 2,000 | 18,359 | 7,000 | 23 359 |
| N ... ... ... | 6,720 | 250 | 6,970 | 830 | 7,550 |
| O ... ... ... | 9,132 | 1,000 | 10,132 | 2,500 | 11,632 |
| P ... ... ... | 4,257 | 250 | 4,507 | 1,750 | 6,007 |
| Q ... ... ... | 10,093 | 2,274 | 12,367 | 15,274 | 25,367 |
| Total ... | 114,965 | 12,774 | 127,739 | 55,514 | 170,479 |

The numbers in columns 4 and 6 are probably a little in excess of what the actuals will be; but in such cases it is as well to allow a margin. You will, of course, notice that the rate of calculated increase in population in the different Peths is not uniform; but this is because some have a greater capacity for expanding than others which are already crowded, as judged by the houses shown on the general plan of the city (sheet No. 1), and the areas available for building.

*Velocity in, and Gradients of, Sewers.*

72. The other factor to be considered in calculating the sizes and gradients of the sewers is the velocity of flow necessary to make the sewers "self-cleansing." Colonel Ducat, in his scheme, has taken a velocity of 2½ feet per second, which is in accordance with the English practice; but experience has shown that this is not sufficient for Indian towns, owing to the fact that sand, &c., is largely used for cleaning the culinary vessels, so that a considerable quantity of silt must find its way into the sewers; and to carry this silt along, it is necessary that a velocity of at least 3 feet per second should be attained. In Bombay the calculations for their new scheme are based on a velocity of 3¼ feet per second; but with the efficient flushing provided for in your scheme, a velocity of 3 feet per second will be quite sufficient; and it has been found to be so at Karachi, where the flushing arrangements are similar to yours; and the sewers have worked satisfactorily there.

73. Under these conditions, the flattest gradients of the various sized sewers, and the populations they would serve, are given in table B.

TABLE **B.**

| Diameter of Sewers in inches. | Flattest gradient suitable for self cleansing velocity. 1 in :— | Population served when sewers are flowing half full. |
|---|---|---|
| 5 | 85 | 3,000 |
| 6 | 106 | 4,000 |
| 7 | 127 | 6,000 |
| 9 | 172 | 9,900 |
| 12 | 243 | 17,600 |
| 15 | 318 | 27,500 |
| 18 | 396 | 39,600 |
| 21 | 476 | 54,000 |
| 36 | 909 | 158,800 |
| 39 | 1,000 | 186,300 |
| 42 | 1,100 | 216,000 |

In thus estimating the population capable of being served by any size of sewer, the maximum flow of sewage during any part of the day has been assumed to be equal to the whole day's sewage being passed through the sewer in 800 minutes.

*Minimum Size of Sewers.*

74. For practical reasons, it is impossible to adjust the sizes of the smaller sewers in proportion to the work they have to do, as there is a minimum diameter below which it is not desirable to go. Some engineers in England insist on nine inches as a minimum for street sewers, for convenience of sighting and cleaning; others will put down sewers of six, or even five inches, looking more to first cost, and the cost of the necessary flushing water. In Rangoon the minimum size was six inches, but there they were all of cast iron, and economy in size was essential. In your case, for considerations of gradient, &c., a minimum size of seven inches for stoneware street sewers has been adopted, and these are shown by thin red lines on the city plans; larger sizes are shown by thick red lines. For house-connections, four inches is the minimum size, to allow of the removal of vegetable and animal refuse, &c., and also to allow cleaning rods and appliances passing through.

*Flushing Tanks.*

75. To prevent the silting up of the minimum size of street sewers, where this size is in excess of the work that such a sewer has to do in any locality, as well as to provide a recurring intense rush of sewage in all the sewers, in order to counteract any tendency to silt up through-

out the whole system, automatic flushing tanks have been provided at the heads of the longer runs of sewers, to be supplied with water from the public mains ; this supply being regulated to allow of a flush at least once in twenty-four hours ; and on the shorter runs of sewers, flushing sluice gates have been provided in the head manholes, which can be filled with water from a hose, or from a convenient pipe laid to each, by a man going round periodically ; and opening the gate when the manhole has been filled to a depth of three or four feet. In certain cases the sewage from ejectors is delivered into automatic flushing tanks, and utilised for flushing the major collecting sewer, instead of needlessly using potable water for this purpose. The signs by which the positions of the various flushing tanks and sluices are indicated on the plans, are given on the reference sheet.

[redacted]*nholes.*

76. To facilitate sighting through, and cleansing of, the sewers, manholes have been provided at every change in direction and gradient ; so that between these manholes the sewers should lie in straight lines, and, if properly laid, obstructions can easily be seen, and readily removed by suitable cleansing rods and appliances.

*Junctions of Sewers.*

77. In all cases where a smaller sewer debouches into a larger one, a drop is allowed for ; so that the smaller sewer shall always have a free discharge into the larger. The minimum drop allowed is such that the invert of the smaller sewer shall not be below the horizontal diameter of the larger. When sewers of the same size lead into the same manhole, the inverts of the discharging sewers should, where practicable, be higher than that of the receiving sewers, especially where the former enter the manhole more or less at right angles to the latter.

*Gravitation Area of City.*

78. The general city plan (sheet No. 1) shows that the sewage of the southern and eastern portions of the city will gravitate to the outfall, but that of the northern and western portions must be raised mechanically at various points. The line bordered by a broad red band on this plan, shows the boundary of the gravitation area.

*Primary, Secondary and Major Collecting Sewers.*

79. The reticulation of the sewers may be divided into primary, secondary and major collecting sewers, the primary being the smallest and shortest, the secondary being larger in diameter (nine to eighteen inches), receiving the sewage from the primary and delivering their sewage into the major collecting sewer. The head of this latter is near the Khunya Murlidhur, and its effective size there must be equivalent to a diameter of eighteen inches ; its invert level at this point is 164·70. The course of the major collecting sewer is generally in a north-eastern direction to the outfall, which latter is about 400 yards to the north-west of the railway station. Along its length, this sewer receives the sewage from the secondary sewers, and also that which is raised mechanically from the lower portions of the city ; its size being increased at intervals, proportionately to the volume it has to carry in the various portions.

Table **C** gives the lengths, and the equivalent diameters, of the major collecting sewer, from its head to the outfall.

TABLE **C.**

| Equivalent Diameter in inches. | Length in feet. | Remarks. |
|---|---|---|
| 18 | 3,622 | From automatic flushing tank near Khunya Murlidhur. |
| 21 | 519 | |
| 39 | 1,543 | |
| 24 | 2,335 | Cast-iron inverted syphon to junction with Sadar bazaar main sewer. |
| 39 | 1,888 | The latter part of this will probably have to be a 27-inch cast-iron inverted syphon, to pass under the railway to the outfall. |
| 42 | 2,600 | |

You will notice that for one intermediate portion this major sewer is reduced from the equivalent diameter of 39 inches to 25 inches, for the Inverted Syphon, which is necessary to carry the sewer across the Nagzeri nullah; as otherwise, the whole of the sewage from the area to the west of that nullah, and a large part of that from the east of that nullah, would have had to be raised mechanically. As this Inverted Syphon must, in the nature of things, always run full, it is obviously necessary, in order to maintain a velocity of three feet per second, that its diameter must be reduced below the equivalent diameter of the preceding portion of the major collecting sewer, which only runs half full. Owing to the cost of carriage, and danger of breakage of large stoneware pipes, this major collecting sewer must be of masonry; built with hard vitrified bricks and cement mortar (one of cement to one of sand), or of cement moulded concrete blocks, and lined with similar cement plaster. It will be egg (or barrel) shaped, and its size in the different lengths will correspond to a circular sewer of the diameters given in table **C**. The Inverted Syphon is to be of cast-iron pipes, with turned and bored joints; and the upper portion (near Phadke's gate) is to be of two lengths of specially made pipes, tapering from 39 to 24 inches in diameter, so as to reduce the friction at entry to a minimum.

*Ejector Stations.*

80. For mechanically raising the sewage of the northern and western portions of the city, four ejector stations are provided, situated as follows:—

(1) About 310 yards to the N.-E. of the Lakri Bridge.

(2) Near the N.-W. corner of Shunwar Wada.

(3) A little to the N.-E. of the Dhakta Sheksalla.

(4) About 70 yards to the N. of the Mangalwar Gate.

These sites have been selected as being the most suitable, and above flood level; as, if flood water entered the sewers, there would be danger of their being surcharged and silted; and extra cost would also be

incurred in mechanically raising this flood water to the outfall. The particulars as to estimated population served, flow of sewage, size of ejectors (which must of course be in duplicate at each station), reduced levels of ground and of inverts of sewers, lifts, and friction, are given in Table **D**.

TABLE **D.**

| DETAILS | EJECTOR STATIONS. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Estimated population in 1931 ... ... | 24,639 | 24,000 | 17,494 | 19,876 |
| Maximum flow of sewage in gallons per minute ... ... ... ... | 616 | 600 | 438 | 497 |
| Size of ejector in gallons ... ... | 500 | 500 | 300 | 300 |
| R. L. of ground ... ... ... | 137·50 | 134·00 | 130·00 | 130·00 |
| Ditto of invert of sewer ... ... | 125·13 | 116·72 | 111·94 | 119·46 |
| Ditto of discharge (at major collecting sewer) ... ... ... ... | 170·00 | 170·00 | 170·00 | 148·00 |
| Net static lift ... ... ... | 44·87 | 53·28 | 58·06 | 28·54 |
| Drop to ejector ... ... ... | 5·67 | 5·67 | 5·19 | 5·19 |
| Gross static lift ... ... ... | 50·54 | 58·95 | 63·25 | 33·73 |
| *Pipe friction*— | | | | |
| I. To flushing tank ... ... | 7·85 | ... | ... | ... |
| II. To junction ... ... ... | ... | 0·94 | ... | ... |
| III. Ditto ... ... ... | ... | ... | 5·74 | ... |
| Junction to flushing tank ... | ... | 4·40 | 4·40 | ... |
| IV. To manhole ... ... ... | ... | ... | ... | 4·55 |
| Dynamic head (sewage) ... ... | 58·39 | 64·29 | 73·39 | 38·28 |
| Ditto lbs. per square inch ... | 26 | 28 | 32 | 17 |
| Air friction ditto ... | 2 | 1 | 1 | ... |
| Total head ditto ... | 28 | 29 | 33 | 17 |

81. No. I ejector station will raise its sewage, through a 14-inch cast-iron main, to the automatic flushing tank placed at the head of the major collecting sewer, to provide for the flushing of that sewer. Nos. II and III ejector stations will raise their sewage, through a 20-inch cast-iron main (with 12 and 14-inch branches to it from the ejectors), into the automatic flushing tank near Shukrawar Gate, to provide for the flushing of the major collecting sewer where it is increased to 39 inches equivalent diameter; and especially for the flushing of the 24-inch Inverted Syphon portion of that sewer. No. IV ejector station will raise its sewage, through a 12-inch cast-iron main, into a manhole on the 42-inch section of the major collecting sewer. The cast-iron mains for conveying the sewage from the ejector stations, are to be similar to the pipes of the Inverted Syphon, *i.e.*, having turned and bored joints; and they are to be provided with sluice and reflux valves as shown on the plan.

*Air Compressing Plant.*

82. The air compressing plant, for supplying power to operate the ejectors, is located at the outfall site; so that the whole establishment connected with the sewerage works (except the itinerant portion which will attend to the street sewers, etc.) may be concentrated at one

point, for economy. The air compressing plant is fully described in the estimate, and is in duplicate, each set consisting of a triple expansion, condensing steam engine, with air compressing cylinders and feed and circulating pumps attached, marine-type boiler with economiser, and an air receiver or accumulator. The buildings will consist of engine and boiler-house, coal store, chimney shaft and offices. The whole installation will be similar to that which has worked so successfully at Karachi. From the accumulators at this central station, the air is conveyed to the ejectors through cast-iron spigot and faucet pipes, jointed with lead, varying from nine inches at the Central station to four inches on the branches connected with Nos. III and IV ejectors. The sizes and courses of the air mains are shown on the general city plan (sheet No. 1) by blue figures and blue lines. More care is required in jointing mains for air than for water ; but experience elsewhere has shown that, with good work and suitable care, they can be jointed without difficulty, so as to ensure that the loss by leakage is less than one per cent. of the maximum supply ; they should be tested as they are laid, and again as a whole, with air compressed to 40 lbs., the joints being smeared with a solution of soap to detect any leakage ; and the contractor should be made responsible for their tightness.

*Ventilation of Sewers.*

83. It is absolutely necessary that all the sewers should be properly ventilated ; because, if provision is not made for this, they will ventilate themselves in a dangerous manner. Ventilation in the past has had to bear the blame of many things for which it is not responsible ; that is to say, if a sewer is badly constructed and has not sufficient fall, no amount of ventilation will convert it into a good sewer ; but the ventilation is often blamed for calling attention to the nuisance caused by such a sewer, as in the case of the Queen's Road in Bombay ; and however well a sewer may be designed and constructed, it may be converted into a sewer of deposit by badly constructed street gullies. Ventilation, to perform its legitimate work effectually, should not be called upon to deal with the foul exhalations from a badly designed or constructed sewer ; but should be applied to well laid, and properly proportioned, graded, and flushed sewers ; in order to deal with the watery vapour arising from the surface of the quickly flowing sewage, before it has time to stagnate and putrefy ; but however well the sewer may be constructed, if the house drains and their fittings are not also properly constructed and flushed, they intermittently send down putrefying sewage, which converts what would otherwise be a good sewer into an offensive one, and for which the ventilation gets the blame. During the twenty-four hours, the sewers contain varying quantities of sewage, flowing in one direction only ; and also, in contact with it and filling the space above the sewage, air, more or less saturated with watery vapour. The sewage flows at a velocity of 3 feet per second, and at this velocity the friction between it and the air in contact with it causes the latter almost invariably to travel in the same direction ; but not at the same rate, as its motion is checked by the friction of the

sewer, and by every opening in the sewer ; and these, in a sewer ventilated only by the surface method, may counteract the effect of the moving sewage ; and the motion of the air may become little better than stagnation, unless there is a good wind. This natural movement may also be modified by differences in temperature between the outer air and that of the sewer ; but more especially in dry weather by the watery vapour always rising from the surface of the sewage, which is a most important factor in sewer ventilation ; it is therefore advisable to assist the natural motion of the sewer air. The sewers of the ejector station districts are ventilated by means of the compressed air after it has done its work in the ejectors. This air is allowed to exhaust from nozzles, one of which is placed in an "Outlet" ventilating shaft erected near each ejector station, and connected at its base with the manhole adjoining the station. All the covers on the sewer manholes are close fitting throughout, except as stated hereafter ; so that no air can get into, or out of, the lines of sewers, except at certain selected points. At the heads of the principal lines of sewers, "Inlet" ventilating shafts are erected, the bases of which are connected with the head manholes, or flushing tanks, as the case may be. The exhaust air from the ejectors rushes upwards out of the nozzles with considerable force, and induces large currents of air to follow it, which can only find their way to the outlet shafts by entering at the inlet shafts, and thus passing along the entire lengths of the sewers ; the air in the sewers is thus continually replaced by fresh air each time the ejectors act, and cannot get fouled appreciably, especially as, owing to the rapid passage of the sewage through the sewers, it is delivered fresh at the outfall, and has no time to decompose on the way; sewage entering at even the most distant point of the system will be delivered at the outlet within two hours. The positions of these ventilating arrangements are given on the general city plan (sheet No. 1), and their details are shown on sheet No. 7. For the ventilation of the *gravitation* area of the city, an "outlet" ventilating shaft is provided near the upper end of the Inverted Syphon, on the major collecting sewer ; and also at the lower end of that sewer at the outfall ; and "Inlet" shafts are placed at the heads of the longer lines of sewers, as in the former case. Nozzles are fixed in these two outlet shafts, similar to those in connection with the ejector stations, and are supplied with compressed air direct from the air mains. On the shorter lengths of sewers throughout the city, the covers of the *head* manholes (*i.e.*, those having flushing sluice gates) are to have a few perforations in them, to admit of small quantities of air entering the sewers when the nozzles in the above two outlet shafts are operating. By these means, positive ventilation of the whole lengths of the sewers is ensured.

*Cantonment Drainage Scheme.*

84. I now come to the proposals for efficiently draining the Sadar Bazaar. Looking to its position, which is immediately adjoining the city, and is also close to and directly to windward (for a great part of the year) of the cantonments generally, and to the fact that its sanitation is even worse than that of the city, and that its population is about one-

third of that of the city, and its density probably greater, I think it is essential that its scientific drainage should be undertaken *concurrently* with that of the city ; especially as its sewage would otherwise pass, as it does now, down the Manik Nullah, and through a portion of the city, into the river. Everything that I have said about the sanitary evils in the city applies even *more* strongly to the Sadar Bazaar. Its four sewers are nothing but leaky cesspools, which give out such sickening odours every hot weather that the people in Main Street and the adjoining parts can hardly live there then. This has been repeatedly acknowledged by the cantonment authorities, and it is to be hoped that Government, if only in the interests of the troops, will aid those authorities in remedying this terrible state of things. The one saving clause is that they have a pure water-supply ; but the experience of other places under similar circumstances has shown that it only wants a favourable state of things to cause a serious outbreak of disease ; and sooner or later this is sure to occur, as the ground is yearly becoming more and more saturated with foul leakage from the so-called sewers. Fortunately the Military Department are prepared to take up the matter, and G. R. No. 1677 of 18th April 1899, G. D., quotes a letter from the Military Department of the Government of India, in which it is said that they :—"attach great "importance to the sanitation and the efficient drainage of the city "and cantonment at Poona." The Bombay Military authorities also strongly favour the septic tank system of treatment. The plans and estimates for the Sadar Bazaar scheme will be forwarded to the Military Department for approval, but it will be as well for me to describe to you its general features.

85. The natural outfall for the Sadar Bazaar drainage is the same as for the City drainage ; and the whole of the sewers of the former converge to an 18-inch secondary sewer, which debouches into the city major collecting sewer where the latter is increased from 39 to 42 inches equivalent diameter. If it is decided to keep the two schemes separate and distinct, then the city major collecting sewer should be continued to the outfall with a diameter of 39 inches, and the Sadar Bazaar sewer continued to the outfall with a diameter of 18 inches ; but I think it would obviously be waste of money to have separate outfall sewers, and outfall treatment works, for the two areas; and this applies not only to the capital cost, but to the annual working expenses. The natural drainage of the Sadar Bazaar is, as I have said, towards the city major collecting sewer, and no advantage can be gained in any way by dividing the interests of the two areas in the major sewer and outfall works.

86. On a separate tracing (sheet No. 2) the lines of sewers, &c., suitable for the Sadar Bazaar area are shown ; and what I have said in detail as to the city scheme will apply also to the other, except that the *whole* of the sewage of the latter will flow by *gravitation* to the outfall. The ventilation of the cantonment system of sewers is provided for by

the outlet ventilating shaft at the outfall end of the major collecting sewer, which also commands the gravitation portion of the city. As in the city, air inlet shafts are provided at each of the (13) automatic flushing tanks, and a ventilated cover is to be provided for every manhole with a flushing sluice. When the compressed air supply to the nozzle in the outlet shaft is once regulated, it will remain constant ; and require little attention, except occasionally for cleaning purposes. The population provided for is only that of the Sadar and Sholapore Bazaars, but this comprises four-fifths of the population of the whole of the Cantonment ; and as the pipes are calculated, in the usual way, to carry the sewage of this area when flowing half full, they can (as in the case of the city) carry double this volume, or any intermediate amount, with an equal efficiency; so that there will be no difficulty hereafter in designing a suitable scheme for the rest of cantonments, and fitting it into the present scheme without any alteration to the latter, as the *extra* number of people to be provided for will only be about *one-fourth* of that for which the Sadar Bazaar scheme is designed.

*Description of Plans.*

87. It will now be convenient to describe the plans, even at the risk of repeating some of what I have already said.

*Sheet No.* 1 is a general plan of the City, on which the 7-inch sewers are shewn by thin red lines, and the larger ones by thick red lines. The arrow heads show the direction of flow ; and the levels in *red* figures are the reduced levels of the inverts of sewers at the points indicated. All reduced levels are referred to the Irrigation Datum, which is 50·83 feet below that used by the Municipality ; *i.e.*, to reduce any of the reduced levels shown on these plans to the Municipal Datum, 50·83 must be deducted from such reduced levels. On this plan, the positions of automatic flushing tanks, flushing manholes, ejector stations, ventilating shafts, air compressing station, and the lines of air and sewage mains are shown ; the signs representing these various works are explained on the reference sheet for this plan. On this plan, the line with a broad red border indicates the division between the area from which the sewage will reach the outfall by gravitation, and the area in which the sewage must be raised mechanically. The latter is subdivided into four districts, in each of which the sewage gravitates to an ejector station, and the boundaries of these districts are bordered by narrower red bands. The same information, but in a more detailed manner, is given in the 45 sheets of the city plan on the larger scale.

*Sheet No.* 2 gives similar details regarding the Cantonment Scheme. *Sheets Nos.* 18 *to* 22 are longitudinal sections along the lines of sewers in the City, and *Sheet No.* 23 are similar sections for the Cantonment scheme.

*Sheet No.* 3 shows details of construction of manholes. These can be constructed in concrete, similar to those at Karachi (as described in the "Final Report on the Drainage Scheme for the Native town of Karachi");

which would probably be somewhat cheaper than brick, as the walls could be reduced to nine inches in thickness instead of fourteen inches; and the manholes could also be made circular, with moulded concrete.

*Sheet No.* 4 shows details of automatic flushing tanks and flushing sluices, for water-supply; which are to be placed at the heads of the longer runs of 7 and 9-inch sewers, as indicated upon the large scale plans of the city. These also might be constructed in moulded concrete instead of brick work.. The depths of these flushing tanks, and manholes with flushing sluices, must, of course, be according to the reduced levels shown on the general plan (sheet No. 1), at the sites indicated; as the details given on sheet No. 4 are only for an average construction.

*Sheet No.* 5 shows details of automatic flushing tanks for the sewage delivered from the ejectors. These tanks will be on the major collecting sewer, in the positions indicated on the large scale plans of the city.

*Sheet No.* 6 shows details of a masonry ejector station as adopted for Bombay. Cast iron tubbing was used at Karachi, which was necessitated by the high level of the subsoil water at the sites, and may perhaps be required at one or more of the sites here, for the same reason. This tubbing is provided with a "cutting edge," so that the whole of the excavation can be taken from the inside, the several rings being jointed together at, or near to, the surface, as the tubbing is sunk; thus effecting a saving in cost of excavation, timbering, etc. If very considerable quantities of water are met with at any of the sites, a Bull's dredger could be used for the first portion of the sinking, and an air lock for the lower part, so that no pumping of water would be necessary. The middle portion of the tubbing is large enough to allow of the ejectors, etc., being passed down, so that the station can be sunk to its proper depth before putting in the machinery. The automatic air valves may be placed in any convenient position, even above ground; but ought to be as near the station as practicable. A brick (or concrete) water-tight chamber for these valves is shown on the drawing, between the manhole and the ejector station.

*Sheet No.* 7 shows details of the ventilating arrangements. Here also the drawings are for an average construction; and the relative positions of the outlet shaft, silencing chamber, ejector station, and other parts, can be varied in construction to suit the local circumstances surrounding each ejector station.

*Sheets Nos.* 8 *&* 9 give details of the buildings for housing the air compressing plant. The walls are to be built of trap rock, the roof to be covered with Mangalore tiles, the engine foundations can be built with either brick, or Ashlar stone, in cement; or in cement concrete 4 to 1; but the top of the foundations, immediately below the iron engine beds, must be of hard stone in as large blocks as practic-

able, and not less than 12 inches in thickness. The boiler seatings and flues should be of first class bricks set in lime mortar, and the linings, where coloured bright yellow on the drawings, must be of fire bricks set in fire clay. The spaces between walls of boiler seatings and up to floors of flues, where no weight comes on them, may be filled in with clean sand.

*Sheet No.* 10 shows details of the chimney shaft.

*Sheet No.* 11 shows details of the economiser chamber between boilers and chimney. Both the chimney and economiser chamber should be of brick work set in lime mortar ; with linings of fire brick set in fire clay, as shown by the bright yellow coloured portions. The covering of the economiser, over the girders, to be of sandstone slabs set in lime mortar.

*Sheets Nos.* 12 *and* 13 refer to the septic tank outfall works. The latter has been obtained from "the Septic Tank Syndicate", to provide against any mistakes ; and the former has been drawn out in my office. In their forwarding letter they say :—

"We send you herewith a general drawing of the works which we "should recommend in this case ; also a larger scale drawing showing "the tanks and filters in fuller detail, and a full description of the "works. We have provided for a flow of 20 gallons per head per "diem for the estimated population of 1931. If it is decided to provide "only for the present population of the town, the works will be reduced "by two-fifths ; or, if the increase in the town is provided for, and the "Sadar Bazaar excluded, a reduction of one-fifth should be made. The "division of the septic tanks into ten, and of the filters into twenty, will "enable you to make any desired reduction, by simply striking out one "or more units. Our quotation refers to the complete installation ; and "if some of the tanks and filters are omitted, the total will be reduced "approximately in the same proportion.

"We have not taken the maximum flow per minute as the basis "for designing the works ; as this does not affect their capacity, which "depends on the total quantity to be dealt with per day. We have "worked on the same basis of tank capacity and filter area as we use "in this country ; taking no account of the higher temperatures which "occur in India. We may, therefore, fairly expect that the works will "be capable of doing somewhat more than they are designed for. If "furnace clinker for the filters cannot be obtained in sufficient quantity, "burnt clay ballast can doubtless be got at a moderate cost. The clin-"ker is, however, the better material."

*Cost of Septic Tank and Filters.*

88. The Syndicate's price for the valves, and iron work other than constructional (delivered in London), for ten tanks and twenty filter beds, including their Royalty, and for one visit during construction and another at completion, is £12,000. From further enquiries it

appears, however, that they claim no patent rights for the *system*, but merely for the alternating gear ; which I think can be arranged for differently, and in a better way, if the Municipality will allow me to expend up to say Rs. 500 for experiments, and on a working model. For the fittings, I estimate as follows :—

| | Rs. |
|---|---|
| Inlet and outlet valves for tanks, internal pipes and tees, manholes and covers, and wash out pipes, at Rs. 1,500 per tank ... ... ... | 12,000 |
| Necessary valves and pipes for filters, including all connections, at Rs. 1,000 per filter ... ... ... ... ... ... ... | 16,000 |
| Necessary machinery, and automatic alternating gear, for filters, at Rs. 2,500 per filter ... ... ... ... ... ... ... | 40,000 |
| Piping, tees, bends, &c. ... ... ... ... ... ... | 20,000 |
| Erection and fitting of above ... ... ... ... ... ... | 12,000 |

or a total of one lakh for this part of the installation. The local construction of the complete installation, including the above, comes to Rs. 5,50,544, of which one-fourth is debitable to the Cantonment project. Looking to the fact that the action of the Bacteria is more active in this country, and that your water-supply is at present only 15 gallons per head, and that the population in 1901 will probably be a little less than that estimated for, I think we may safely begin with an installation of six tanks, each 750 feet long and 16 feet broad, with a depth of 8 feet of sewage ; and twelve filter beds, each 150 feet long, 106 feet broad, and 5 feet deep, for the City ; and two tanks and four filter beds, similar to the above, for the Cantonment ; and the estimate is drawn out for this number. The filters will contain a depth of 4 feet of furnace clinker, broken to pass through a half inch mesh, and washed. If clinker is not available, burnt clay ballast can be used. Twelve filters will form the working set ; and four will be rested in turn, at intervals of a few days. The extra tanks and beds can be added hereafter, as required, to provide for an increased population in the future. The estimates for the city will be debited with the cost of a 39 inch sewer to the outfall; and the Cantonment estimates with the *extra* cost of a 42 inch (instead of 39 inch) sewer, from the point where their 18 inch sewer joins the City Major Collecting sewer ; and also with the difference between a 24 inch and a 27 inch cast iron pipe, for the inverted syphon under the railway, to the outfall.

*Alternative Scheme for Sewage Farm*

89. I now come to the alternative scheme for a sewage farm. The principle of this is to convey all the sewage to a pumping station near the Fitzgerald Bridge, and to pump it thence to the highest point of site No. 3, near the 5th Milestone on the Ahmednuggur road. The tracing, *Sheet No. 14*, illustrates this scheme; and you will see that a smaller area of the city is required to be served by ejectors, as the Major Collecting Sewer can be placed nearer the river. The new line for this Major Sewer is shown on this tracing by a thick red line. It

will be 24 inches in diameter at its head, near Lakri Bridge, increasing to 42 inches in diameter as it approaches the main pumping station. The respective lengths will be :—

| | | | | | |
|---|---|---|---|---|---|
| 24 | inch | ... | ... | ... | 4,422 feet |
| 30 | ,, | ... | ... | ... | 1,782 ,, |
| 39 | ,, | ... | ... | ... | 3,369 ,, |
| 42 | ,, | ... | ... | ... | 10,311 ,, |

and it would be of moulded concrete, as in the former scheme. The cost will be Rs. 1,39,008. The secondary sewer, of 18 inches diameter, which would receive the Sadar Bazaar sewage and deliver it into the City Major Collecting Sewer, is also shown on the tracing ; and will have to be 2,100 feet longer than in the former scheme.

90. The air compressing plant and accumulators, would, in this case, be located at the main pumping station, near the Fitzgerald Bridge ; and the air main would follow the line of the Major Collecting Sewer, to the Jakat Bridge over the Nagzeri Nallâh ; whence it will branch off to the four ejector stations, the sewage from which will be delivered into the Major Collecting Sewer. Table **F** gives details for these alternative ejector stations, similar to those already given in Table **D** for the septic tank scheme.

TABLE **E**.

| Details. | Ejector Station. | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| Estimated population in 1931 ... ... ... | 6,000 | 6,000 | 5,000 | 6,000 |
| Maximum flow of sewage, in gallons per minute... | 150 | 150 | 125 | 150 |
| Size of Ejector in gallons... ... ... ... | 150 | 150 | 150 | 150 |
| R. L. of ground ... ... ... ... ... | 137·19 | 135·00 | 135·00 | 131·00 |
| Do. Invert of Sewer ... ... ... ... | 125·00 | 123·70 | 117·40 | 112·00 |
| R. L. of Discharge (at Major Collecting Sewer)... | 147·00 | 144·00 | 137·00 | 135·00 |
| Net Static Lift ... ... ... ... ... | 22·00 | 20·30 | 19·60 | 23·00 |
| Drop to Ejector ... ... ... ... ... | 2·92 | 2·92 | 2·92 | 2·92 |
| Gross Static Lift... ... ... ... ... | 24·92 | 23·22 | 22·52 | 25·92 |
| Pipe Friction ... ... ... ... ... | 9·60 | 10·20 | 3·95 | 8·00 |
| Dynamic Head (Sewage)... ... ... ... | 34·52 | 33·42 | 26·47 | 33·92 |
| Do. lbs. per sq. in. ... ... ... ... | 15 | 15 | 12 | 15 |
| Air Friction ditto ... ... ... ... | 4 | 4 | 3 | 3 |
| Total Head ditto ... ... ... ... | 19 | 19 | 15 | 18 |

91. The main pumping machinery would be similar to that erected for the same purpose at Bombay, Calcutta, Southampton, Rotterdam, and other places ; and would consist of three triple expansion Worthington Engines, any two of which will be capable of pumping 3,860 gallons per minute to a static height of 97 feet, through a 24 inch cast iron main, 18,000 feet long. The steam would be provided by two Babcock and Wilcox boilers, either of which will be able to drive two of the above engines at full load. Superheaters to be fitted to each boiler ; and an economiser, with all the necessary bye-passes, and of a size sufficient to work with one boiler when it is doing its maximum. The Condenser to be worked by the sewage water.

The tracing, *Sheet No. 15*, shows the general arrangement of this pumping station.

92. The cost of this Pumping Plant, erected at site, will be about 2½ lakhs; and the Engine House for it will cost Rs. 16,771; the cost of the necessary covered Storage Tanks and Grit Chambers (in duplicate) will be about Rs. 33,000; or a total of three lakhs. The proportional amount of this sum debitable to the Cantonment, as in the case of the Septic Tanks and Filters, will be Rs. 75,000; also, the difference in cost between a 39 inch and a 42 inch sewer, from the point where the Cantonment 18 inch sewer joins the City Major Collecting Sewer, to the Pumping Station—Rs. 3,210; also, the difference between the cost of a 22 inch cast iron Rising Main, from the Pumping Station to the Sewage Farm (which would be sufficient for the city sewage), and the 24 inch Main, which is necessary for the combined sewage; say, Rs. 36,000. The cost of the Farm, including land compensation, laying out, buildings, &c., will probably be three lakhs; of this, one-fourth will be debitable to the Cantonment Scheme, as in the case of the Septic Tank and Filter beds of the other scheme. The coal required for pumping to the Farm will cost about Rs. 24,000 per annum, and the Engine Room Establishment about Rs. 4,000 per annum, or a total of Rs. 28,000 for these Working Expenses; which must also be divided in the above proportion. No account is taken of the Farm Establishment, as the Farm will certainly work at a moderate net profit, if managed on the lines of the Karachi Farm. For the purposes of comparison, the cost of the Sewage Works in the City, exclusive of the Air and Sewage Mains, Ejectors, Major Collecting Sewer, and Outfall Works, of the Septic Tank Scheme, may be taken as the same for both schemes.

*House connections.*

93. As regards house connections, it is *essential* that these should be carried out in a sound and proper manner; and I think it is absolutely necessary that they should be done by the Municipality, for the house owners, as "Public Improvements"; charging each owner, as is done in England, a rate sufficient to pay the interest at 5 per cent. and the yearly sinking fund for 20 years, for the amount spent on his house. A monthly charge of one rupee for each connection and W. C. will cover the cost. The revised District Municipal Act will, I understand, contain a provision on this head, in accordance with the English practice. This necessary work can *only* be done satisfactorily in this way; as, if left to the owners, even those who could afford to lay out the lump sum, will probably exercise an unwise economy; using inferior materials, and employing inefficient Plumbers, with a disastrous result; and very many would be quite unable to pay the necessary amount in *one* payment. Experience has shown that, even in England, this is the only way in which such work can be carried out rapidly and satisfactorily; and the reasons apply with even more force to this country. The results obtained are, that the work is done well, quickly, and uniformly; the yearly payments can be easily met by the owners; and it costs the Municipality nothing in the end. Ahmedabad has satisfactorily solved the problem of house connections for ordinary native houses, and the details are shown on the Tracings, *Sheets Nos.* 16 *and* 17. The cost,

including a 3-gallon syphon flushing tank, and "Hindostan" pattern pan with top and foot rests, traps, pipes, and connections to privy and nahni, will average Rs. 125. The number of houses to be provided for in the City is at present about 13,000, of which about 8,000 will require connections, &c., at first. In the Sadar Bazaar the number is 3,419, and in the Sholapore Bazaar 278 ; the number of private privies in these two Bazaars is 1,911, and 127, respectively.

*Periods of construction of Drainage Scheme.*

94. During the first year all the English materials and plant should be ordered, the engine house built, and the tanks and filter beds started. The pumping machinery for the Hadapsar Farm should also be ordered in the latter part of this year. During the second year the pipe-laying can be pushed on, manholes, etc., constructed, machinery erected, and the tanks and filter beds finished, and the Rising Main to the Farm ordered. In the third year the pipe-laying can be finished, and the house connections made ; the Farm taken up and laid out, and the reservoirs built. The relative experience of Surat and Ahmedabad has proved that it is unadvisable to levy a tax for such work until it is finished, and the people are able to appreciate the benefits obtained ; and then, as in the case of Ahmedabad, they do not object to pay. In Surat the people had to pay the extra tax for the three years of construction, and there was much discontent. I would, therefore, suggest that the permission of Government be obtained to the yearly instalments for Interest and Sinking Fund being debited to the Capital Account during construction, and added to the Estimate for works, as is done in the case of Railways ; and also, that Government be asked to allow the loan to be for the period of thirty years ; and to be taken up as required for each year's expenditure, as stated in the Appendix **D**. Looking to the permanent nature of the work, and to the fact that the calculations cover the maximum future population of 1931, I think that a loan for 30, instead of the usual 20 years, may fairly be asked for. The annual amount to be paid per lakh, at 5 per cent., for 30 years, is Rs. 6,505, in half-yearly instalments, as laid down by the Accountant General, for Interest and Sinking Fund. The yearly instalment to be paid by the Municipality, as above, for the Septic Tank Scheme after completion, is given in the Appendix **D**. The Irrigation Revenue from the effluent has been taken at a minimum ; but any extra taxation can always be reduced hereafter, as the revenue from this increases.

*Working expenses for Septic Tank Scheme.*

95. The yearly working expenses for the Septic Tank Scheme, will be :—

| | | Rs. |
|---|---|---|
| 500 | tons of Singareni coal at Rs. 15 ... ... ... ... ... | 7,500 |
| 1 | Engineer at Rs. 150 per month ... ... ... ... ... | 1,800 |
| 1 | „ at Rs. 60 „ „ ... ... ... ... ... | 720 |
| 4 | Firemen at Rs. 15 each per month ... ... ... ... | 720 |
| 2 | Oilers at Rs. 15 each „ „ ... ... ... ... | 360 |
| | City Establishment, say, ... ... ... ... ... ... | 900 |
| | Total ... | Rs. 12,000 |

For the Sewage, or Effluent Farm Scheme, Rs. 21,000 must be added to this, for coal, &c., for the pumping engines, provided the same boilers are used for these and the air compressing plant. If separate boilers are used, the cost will be Rs. 4,000 more. I would suggest that the best means of financing the project should be considered by a representative Committee of the Municipality. The Government of India have recently stated definitely that the larger Municipalities, which presumably are able to raise a loan for such works in the open market, must, as a rule, do so ; and that the limited amount of money available for Government loans, must be reserved for the smaller Municipalities ; which would probably have to pay a high rate of interest to the Market, as their credit is not so good. From enquiries I have made, I think you would only waste time (as Hyderabad did) in approaching Government for a loan ; and I would suggest your ascertaining as soon as possible, as the Bombay Municipality does, at what rate you could get accommodated by the Public. As the Government of India are not issuing a loan this year, there will probably be no stringency in the money market ; and you ought to have no difficulty in floating loans at 5 per cent. for 30 years, as required from time to time, for the expenditure of each of the three years of construction.

*Cost of profitable utilisation of the effluent.*

96. As regards getting a money return from the sewage, I think it will be far preferable to pump the *effluent* to the site near Hadapsar, than to pump the sewage to site No. 3 ; as there will be no danger of the land getting "sewage sick," nor any trouble in dealing with the liquid, and a *far* larger return will be got. The cost of machinery and engine house, and working expenses, will be the same in each case, and the financial results of the Hadapsar farm may be thus stated*—

| | Rs. |
|---|---|
| Machinery and erection ... ... ... | 2,50,000 |
| Engine House ... ... ... ... | 17,000 |
| 21,000 feet of 24 inch cast iron piping, with the necessary valves, &c. ... ... ... | 3,00,000 |
| An open Storage Reservoir to hold about 2,00,000 c.ft., at each end of the rising main ... ... | 33,000 |
| Land Compensation, &c., 500 acres south of Canal... | 1,00,000 |
| 300 „ north of „ ... | 1,00,000 |
| Total Rs. | 8,00,000 |
| Yearly cost of above at 5 per cent. for 30 years, at Rs. 6,500 per lakh... ... ... „ | 52,000 |
| Working expenses of Machinery per annum „ | 28,000 |
| Total Rs. | 80,000 |

*Net* revenue, allowing for cost of working the land, &c., as per Mr. Mollison's data :—

| | Rs. |
|---|---|
| 500 acres Sugarcane at Rs. 250 ... ... ... | 1,25,000 |
| 300 „ Fodder crops at Rs. 150 ... ... ... | 45,000 |
| Total... ... Rs. | 1,70,000 |

so that from the *net* profit you could afford to pay up to Rs. 800, or even Rs. 1,000 a month to a really first class man as Farm Manager (who would

* *Note.—For revised calculations, see Appendix D, and the Estimate for Effluent Farm in Appendix C.*

be essential); and still have Rs. 80,000 a year *at least* left, which will be enough to cover a loan of twelve lakhs for the drainage project; and this, with the six lakhs covered by the Rs. 40,000 that you will save on your present system, will give you enough for the cost of the actual drainage scheme, exclusive of the 8 lakhs loan for the farm, &c. This is only an approximate statement, a more accurate one will be given in the appendix, with Mr. Mollison's report on the crop experiments. Mr. Mollison is just going on a year's furlough, and I would suggest that he be asked to select, and bring out with him for training for two years, a practical man, to start on Rs. 300 a month; with an increment of Rs. 50 per month every two years, if he gives satisfaction; and a pension, as in the U. C. S. His passage money should also be given; and a proviso made that the Municipality can terminate the arrangement at any time with a year's notice, or by giving a year's pay, and his return passage to England. Gross incompetence or misconduct to entail summary dismissal, with the consent of Government; and without any compensation. The machinery will be similar to that for the sewage farm scheme, the Engines will be in triplicate, any two of which will be able to pump 3,860 gallons per minute to a static height of 136 feet, plus 54 feet for the friction in 7,000 yards of 24 inch pipe. A travelling crane, spare parts, and tools, will also be provided. For three million gallons of effluent, the Engines will have to work about 12 hours a day; and for the full future amount, the maximum working time will be 18 hours a day. The above machinery will cost £ 15,500, delivered at site, erected, and set to work, and the working will be supervised for one month; but this price is exclusive of all builders work.

If this proposal is adopted, as I think it must be, it would be advisable to dispense with the separate boilers for the air compressors; and to increase the size of the pumping engine boilers, so as to work the whole plant. This will give a saving in both first cost, and in working expenses. This part of the project should be carried out concurrently with the drainage scheme, so that the effluent may be profitably utilised as soon as it is available.

*Sources from which details have been procured.*

97. In conclusion, I can only assure you that every pains have been taken to make the project as complete and correct in every way as possible. Local rates have been adopted where suitable, and the rates for sewers have been deduced from the work actually carried out in Ahmedabad, Bombay and Karáchi. The general idea for the septic tank and filters was got from the Syndicate. Particulars of the pumping machinery were got from Messrs. Simpson and Co., whose engines are far the most economical for such work. Details of the ejectors, air compressing plant, and air mains were got from Messrs. Shone and Ault; who have also kindly gone over the whole project, which is now in accordance with their advice; and is, I think, sanitarily perfect. Mr. Shone is one of the leading Sanitary Engineers in England; and his partner, Mr. Ault, has, in addition, had considerable oriental experience; as he

personally assisted in the superintendence of both the Rangoon and Karàchi drainage schemes, which have been so successful ; and he was also consulted about Bombay. The great advantage of the advice and assistance they have given me is therefore obvious ; and I would suggest that, in acknowledgment of the trouble they have taken, they should be appointed Consulting Engineers to the Municipality, and Engineering Agents in England for the purpose of inspecting and certifying as to the quality and suitability of the various materials which will be required for the works.

*Relative cost of prep ration of Ahmedab and Poo schemes.*

98. I may add that Mr. Baldwin Latham charged the Ahmedabad Municipality Rs. 10,000, and Rs. 15,000, respectively, for the two instalments of their drainage scheme ; and made a great favour of not charging more for the second portion ; some of the plans and estimates for which will, moreover, require considerable revision before they can be finally adopted. Your scheme, on the contrary, for a somewhat similar amount of work, has actually cost you about Rs. 1,500 only.

J. C. POTTINGER, M.I.C.E., M. San. Inst.
Superintending Engineer,
Sanitary Engineer and Member
of the Sanitary Board.

POONA, *August* 1899.

## APPENDIX A.

## Note by the Chief Engineer, Public Works Department, on the Poona City Drainage Scheme.

The City of Poona extends for about 2 miles in length, along the right bank of the Mutha river, immediately above its junction with the Mulla river ; and extends in depth for about 1½ miles, up to the Mootha Mulla canal which forms its southern boundary. The fall of the ground from the canal to the river is about 90 feet, or an average slope of about 1 foot in every hundred feet ; while the fall from the extreme south-western corner of the City, along the Mutha river to its junction with the Mulla river, is about 20 feet, giving roughly a slope of about 10 feet per mile.

The population of the City in 1891 was 114,965, and the increase per annum of the previous 10 years was 1,554.

2. A tributary of the Mutha river, called the Nagzeri nulla, flows from South to North, and joins that river close to its junction with the Mulla river. This nulla forms the Eastern boundary of the City, and separates it from the Cantonment, the Saddar Bazar, and the European quarters.

The Cantonment is situated at the extreme South, its site being about 100 feet higher than the highest part of the City. The distance from the Southern end of the Cantonment, to the river, is about 3 miles. The first half mile is covered by the Cantonment, built on ground falling 60 feet in that length, or at an average rate of about 2¼ feet in every hundred feet ; then comes the Saddar Bazar, extending for about a mile, and built on ground falling about 50 feet in that distance, or at the rate of nearly 1 foot in every hundred feet ; and finally comes the European quarter, extending for about another mile, with an average fall of about 1 foot in every hundred feet.

The population of the Sholapur and Saddar Bazars in 1891 was 26,815, and the increase per annum of the previous 10 years was 348.

3. From the above, it will be seen that the City site, as well as the Cantonment and Saddar Bazar, admit of being easily and efficiently drained towards the river ; where, on arrival, the sewage has to be disposed of in a sanitary manner.

The Sanitary Engineer, in the accompanying papers, makes two proposals with regard to this, *viz.*, (1) the disposal of the crude sewage by pumping it on to a sewage farm ; and (2) to treat the sewage biologically. The lines of drainage for City, Cantonment, and Saddar Bazar are very similar in both cases.

4. For proposal (1), the following are the main features of the drainage scheme :—

A large intercepting sewer is to be constructed, beginning at the South-Western end of the City and extending along the right bank of the Mutha river to its junction with the Mulla river, and then along its right bank *to the Wellesley Bridge*, near the *Bund Gardens*; into this sewer will gravitate the whole sewage of the City, Cantonment, and Saddar Bazar (and European quarters if required), except that from four small low-lying portions of the City, which will require to be raised. This raising is proposed to be done by means of four of Shone's ejectors. The sewage on its arrival at the Wellesley Bridge outfall will there be pumped up to a sewage farm situated on the Nagar road, and there utilised to irrigate crops.

The estimated cost of this scheme comes to Rs. 20,68,608; and the annual working expenses to Rs. 33,000, to which has to be added Rs. 1,40,000, the sum annually required for 30 years to pay interest and sinking fund on the money borrowed for carrying out the project, including the interest on loans during construction; making a total annual charge against the Municipality of Rs. 1,73,000.

5. The following are the main features of proposal (2) :-

The sewage of three-fourths of the City will gravitate into an intercepting sewer, which is to be constructed parallel to the Mutha river and at a distance of about half a mile away from it; its outfall being situated close to the river bank, to the North-West of the Railway Station, and on the site of the present Plague Camp. The sewage of the Cantonment and Saddar Bazar will gravitate to this sewer, joining it about 3,000 feet from the outfall. The remaining portion of the City, *viz.*, that situated along the river bank, is to be divided into four districts, the sewage from which will be raised by means of Shone's ejectors. The sewage from three of the districts will be discharged into flushing tanks, situated on, and commanding, the intercepting sewer; while that of the fourth will be discharged direct into the sewer, about 1,200 feet from the outfall. The whole sewage, on its arrival at the outfall, is to be treated biologically; first it will flow into 8 specially designed tanks and there be acted on by anaërobic microbes; and from these it will pass through 16 filters filled with 4 feet of burnt clinker, in which it will be acted on by aërobic microbes, the effluent can then either be passed direct into the river, or be pumped up to a farm and there utilised for irrigating crops. The estimated cost of this scheme, without an effluent farm, is Rs. 18,13,584; and its annual working

expenses will be Rs. 12,000, to which has to be added Rs. 1,30,000, the annual sum required to pay off the loan ; thus the total yearly cost of dealing with the sewage will be Rs. 1,42,000. If the scheme is combined with a farm for utilising the effluent, then the estimated cost comes to Rs. 28,00,000, the annual working expenses to Rs. 33,000, and the yearly cost to Rs. 2,13,000 ; which includes Rs. 1,80,000, the annual sum required to pay off the loan in 30 years. The farm, however, is estimated to bring in an annual revenue of Rs. 2,10,000. Deducting this from the above, we get the yearly charge against the Municipality for disposing of the sewage of City and Cantonment to be Rs. 3,000.*

The above is a brief sketch of the arrangements proposed for the collection and disposal of the sewage of the City.

6. The sole object of a City drainage scheme is the removal of the sullage and sewage of its inhabitants. The most important points, therefore, in a scheme of this nature, are the connections of the houses, public latrines, and urinals with the sewers. The Sanitary Engineer proposes that the Municipality should carry out these connections from borrowed money, recovering the actual cost, plus interest, from the house-owners, by levying a monthly charge of Re. 1 per house so connected. This is a proposal which cannot be too strongly supported ; as unless house connections are properly and speedily carried out, a drainage scheme can never be a success ; and the above proposal will ensure this.

7. The next important point is the conveyance of the sullage and sewage as quickly as possible to a suitable outfall, where it can be finally disposed of in the most sanitary manner possible. I have not had time to go closely into the details of the several sewers, &c., but, from the Sanitary Engineer's report, I am perfectly satisfied that in both the schemes they have been designed in close accordance with the latest sanitary knowledge ; their capacity is, I consider, adequate for the present and future requirements ; and their gradients are such as will ensure a continuous flow without any risk of deposit ; while ample and efficient arrangements are provided for thorough flushing.

That sewers can, without any difficulty, be laid as water-tight in this country as in England has been clearly demonstrated in the case of the Ahmedabad drainage, where I have personally seen sewers, several hundreds of feet in length, successfully tested.

With carefully laid sewers, combined with properly trapped and constructed house connections, there will be no danger to the inhabitants.

8. Comparing the two schemes, I have no hesitation in recommending that which provides for the biological treatment of the sewage, and for the final disposal of its effluent on a farm.

* *Note.*—This was written before Mr. Mollison's Report had been received.

The biological treatment of sewage is *the* treatment now advocated by all the highest Sanitary experts in England, and is being adopted in all new schemes of drainage. The experiments which are being carried out at Poona as regards the manurial value of the effluent after being biologically treated, and which I have inspected, in my opinion prove that the effluent is very valuable ; and I would strongly recommend its being utilised as proposed, in which event there is no doubt that it will prove very remunerative to the Municipality.

9. As pointed out by the Sanitary Engineer, the most essential factor in ensuring that a sewage or effluent farm will be a success, is the employment from the first of a *trained* and competent man to look after it. This is very clear from a comparison of the farms at Ahmedabad and Karachi, with both of which I am personally acquainted. I would, therefore, strongly recommend that the Sanitary Engineer's proposal for getting a suitable man out from England should be adopted, and that he should be trained for this special work under Mr. Mollison.

10. I concur entirely with the Sanitary Engineer in his remarks regarding the present unsatisfactory state of the drainage of the Sholapur and the Saddar Bazárs ; and would advise strongly, that their drainage, the proposals for which are approved, should be carried out at the same time as that of the City.

11. In conclusion, I would add that, considering the permanent nature of the work proposed, 30 years would appear to be a reasonable period in which to repay the loan ; especially as the works provide for the future population in 1931.

The following four statements are attached for information :—*

(1) Comparative Statement, showing cost of disposing of the Sewage of Poona City.

(2) Loans required—Ordinary Sewage disposal, with farm.

(3) Loans required—Septic Tank—Disposal without effluent Farm.

(4) Comparative Statement showing probable annual cost of disposing of Poona City Sewage by (1) Ordinary Sewage farm, and (2) Septic Tanks.

S. B. DOIG, M. INST. C. E.,

*9th August* 1899. *Chief Engineer, P. W. Department.*

* *See Note on previous page. For Revised Statement of Cost, &c., see Appendix D.*

## I.

*Comparative Statement showing cost of disposing of the Sewage of Poona City.*

| Items as per abstract. | Septic Tank Proposal without Effluent Farm. | | Cost Rs. | Items as per abstract. | Ordinary Sewage Farm proposal including Farm. | | Cost Rs. |
|---|---|---|---|---|---|---|---|
| | | Rs. | | | | Rs. | |
| 1 | Sewers, Manholes, etc. ... ... | 5,56,486 | | 1 | Sewers, Manholes, etc. ... ... | 6,45,211 | |
| 2 to 8 | Manholes, Flushing Tanks, etc. ... | 1,79,737 | | | | | |
| 9 | Iron Sewage Mains. | 95,865 | | 2 | Air and Sewage Mains ... | 2,01,948 | |
| 10 | „ Air Mains ... | 37,804 | | | | | |
| | | | 8,69,892 | | | | 8,47,159 |
| 11 | Syphon for Nagzari Nulla ... | | 37,990 | 3 | Syphon for Nagzari Nulla ... | | 37,990 |
| 12 | Engine House for Air Compressing Plant ... ... | | 17,876 | 5 | Engine House for Air Compressing Plant ... ... | | 17,876 |
| 13 | Four Ejector Chambers ... | | 10,719 | 7 | Four Ejector Chambers ... | | 10,719 |
| 14 | Chimney Shaft ... ... | | 9,290 | 6 | Chimney Shaft ... ... | | 9,290 |
| 15 | Septic Tanks, etc.... | 5,50,544 | | 4 | Air Compressing Plant ... ... | 2,40,000 | |
| 16 | Ejectors, Machinery, etc. ... ... | 3,54,750 | | 8 | Major Collecting Sewer ... ... | 90,012 | |
| 17 | Land Compensation. | 36,000 | | 9 | Rising Main ... | 2,70,000 | |
| | | 9,41,294 | | 10 | Sewage Farm ... | 2,25,000 | |
| | *Deduct*—As per Abstract ... ... | 1,43,230 | | 11 | Pumping Engines... | 2,40,000 | |
| | | | 7,98,064 | | | | 10,66,012 |
| | *Add*—Establishment and Tools and Plant at 4 per cent. ... | | 69,753 | | Establishment and Tools and Plant at 4 per cent. ... | | 79,562 |
| | Total Cost ... | | 18,13,584 | | Total Cost .... | | 20,68,608 |
| | Working Expenses ... | | 12,000 | | Working Expenses ... | | 33,000 |

## II.

### Loans Required.

*Ordinary Sewage Disposal, with farm.*

| | | | |
|---|---|---|---|
| 1st year—Drainage ... ... ... ... | 10,00,000 | | |
| Total ... | | 10,00,000 | |
| 2nd year—Drainage ... ... ... ... | 6,50,000 | | |
| Farm ... ... ... ... | 2,25,000 | | |
| Interest and Sinking Fund on 10 lakhs ... ... ... | 63,630 | | |
| | 9,38,630 | | |
| Total ... | | 19,38,630 | |
| 3rd year—Drainage ... ... ... ... | 1,12,046 | | |
| Interest and Sinking Fund on 19 lakhs ... ... ... | 1,20,897 | | |
| | 2,32,943 | | |
| Total ... | | 21,71,573 | |
| 4th year—Interest and Sinking Fund on 22 lakhs, say ... ... ... | 1,40,000 | | |
| Working Expenses ... ... | 33,000 | | |
| Total yearly cost ... | | 1,73,000 | (I) |

## III.

LOANS REQUIRED.

*Septic Tank Disposal, without effluent farm.*

| | | | |
|---|---|---|---|
| 1st year—Drainage scheme ... ... ... | 10,00,000 | | |
| Total ... | | 10,00,000 | |
| 2nd year—Drainage ... ... ... ... | 6,50,000 | | |
| Interest and Sinking Fund on 10 lakhs ... ... ... ... | 63,630 | | |
| | 7,13,630 | | |
| Total ... | | 17,13,630 | |
| 3rd year—Drainage ... ... ... ... | 1,63,000 | | |
| Interest and Sinking Fund on 17 lakhs ... ... ... ... | 1,08,171 | | |
| | 2,71,171 | | |
| Total ... | | 19,84,801 | |
| 4th year—Interest and Sinking Fund on 20 lakhs ... ... ... ... | 1,30,000 | | |
| Working Expenses ... ... | 12,000 | | |
| Total yearly cost ... | | 1,42,000 | (2) |

*Septic Tank Disposal, with effluent farm.*

First three years as per abstract—

| | | | |
|---|---|---|---|
| 4th year—Interest and Sinking Fund on 28 lakhs ... ... ... | 1,80,000 | | |
| Working expenses ... ... | 33,000 | | |
| Total yearly cost... | | 2,13,000 | (3) |

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## IV.

COMPARATIVE STATEMENT SHOWING

*Probable annual cost of disposing of Poona City Sewage by—*

(1) Ordinary sewage farm, and (2) Septic Tanks.

| | Yearly cost. Rs. |
|---|---|
| 1—Ordinary Sewage Farm ... ... ... ... | 1,72,000 |
| 2 (*a*) Septic Tanks without Farm ... ... ... | 1,42,000 |
| (*b*) „ with „ ... 2,13,000 | |
| Deduct— | |
| Probable Revenue from Farm. 2,10,000 | |
| ... | 3,000 |

S. B. DOIG, M. INST. C.E.,
*Chief Engineer, P. W. Department.*

*9th August* 1899.

APPENDIX **B.**

## A Note on Establishing a Sewage Effluent Farm near Poona, and on the results of Experiments with purified sewage on various crops, by J. A. Mollison, Deputy Director of Agriculture.

In the following report I propose to give the results of experiments which were undertaken at the Poona Government Farm, to test the manurial effect, on sugarcane and various fodder crops, of the effluent of sewage which had undergone Bacterial treatment in a septic tank and filter beds in Poona City. These experiments, and further experimentation, are important; because, if the Bacterial method of purifying sewage is applied to the whole of Poona City and Cantonments, such sewage effluent in a large quantity will be available, and probably will be used as a source of manure supply, and of irrigation for land in the neighbourhood of Poona.

2. I will first endeavour to define the conditions favourable for the suitable establishment of a Sewage Effluent Farm. It is probable that purified sewage will show its best results on sugarcane. The cultivation of this crop is, and I think rightly, prohibited within one mile of the Cantonment boundary. The same prohibition would probably apply to crops of any description irrigated with sewage. If land is taken up for a Sewage Farm, it should, I think, be under the canal; because an additional supply of pure water for irrigation may from time to time be necessary, even though the sewage be fully sufficient for the area acquired. The most suitable sugarcane land is near Manjhri, 6 to 8 miles from Poona. It is medium black soil of moderate depth (2 to 3 feet), with a substratum of murum. The combination of such soil above, and porous murum below, secures natural drainage; an important consideration in the case of land which is continuously irrigated. The land for a Sewage Farm should, if possible, be in one block; and the surface should slope so that sewage can be distributed easily. Land of sufficient extent, and having the above requirements, can be obtained about six miles from Poona, adjacent to the Sholapur road and under command of the Canal.

It is not only suitable for sugarcane, but also for such other crops as are likely to succeed under sewage irrigation. It grows sugarcane now, and will in consequence be expensive. The distance from market is considerable, and the disposal of produce will be somewhat more costly than from land situated nearer Poona.

8. Assuming that the ordinary strength of the Poona purified sewage will be in the ratio of 15 to 20 gallons of water per head of population, the effluent of the sewage from the Poona City and Cantonments will, with a normal population, be sufficient to irrigate probably 550 to 600 acres of sugarcane. This calculation is based upon the results of experiments at Manjhri, which were carried out by the Agricultural Department to determine the amount of irrigation water required to give the *best* results, the water being given at moderately short intervals.

The best results were got with 34 waterings in 12 months, and the irrigation water used was equal to 49 inches of rainfall, the additional actual rainfall during that period being about 30 inches. During the monsoon the least amount of irrigation will be required ; and it is impossible that the whole of the purified effluent can be economically disposed of on an area of 600 acres of sugarcane at this season. In any case, a larger area, suitable for sugarcane, must be taken up; because sugarcane cannot be continuously grown on the same land. In the Poona district the crop must be planted at a particular season. The best planting season is between December and March. The crop is propagated in the first instance from "sets" (short pieces of cane). Sugarcane thus planted, ripens in 12 months. When harvested, a stubble should be left. Young shoots spring from the stubble, or root-stocks, and grow into a crop of "Ratoon" cane. The Ratoon crop, if healthy, is fully as profitable as the first crop ; and the cost of sets, and of the preparatory tillage, is saved. These items amount to about Rs. 80 or 90 per acre. A second Ratoon crop is not usually profitable, because it generally becomes unhealthy and patchy. Therefore, two years after the first planting, the crop should be grubbed up. This would probably be in January or February. There is ample time between this date and the following June, to thoroughly clean and fallow the land. In June I would sow a rain-crop of fodder-jowar, which, if helped during breaks in the rains by sewage irrigation, would produce a heavy and profitable crop. A fodder-crop of this class could be reaped in two months; and another grown, and harvested in October or November. The land could then be again got ready for sugarcane by December or January ; a very favourable time for planting.

The rotation would, therefore, be :—

| | |
|---|---|
| 275 acres of new cane<br>275 „ „ Ratoon cane | Irrigated fully with effluent in the fair season, and lightly in the rains. |
| 275 acres of fodder-jowar | Two crops taken between June and November, and irrigated as required with the effluent. |

4. It will be seen further on, that effluent irrigated fodder-crops were grown very successfully at the Poona Farm on light soil. Therefore, I advise that, *in addition* to the above area, about 100 acres of light soil be obtained, on which the effluent could be advantageously used during rainy weather in the monsoon.

A sufficient area of this kind of soil can be obtained near the sugarcane land which I have referred to. Crops which are grown on this kind of soil in the Poona district often fail, owing to deficient rainfall; and are generally poor, because the soil rarely gets enough monsoon rain. Two or three waterings with the effluent during the monsoon would be of great advantage. In any case, failing this provision, it would, I think, be necessary to turn the effluent into the river during heavy monsoon rain, or so long as the sugarcane soil continues sodden, or wet. The disposal of the effluent in this manner would, of course, be wasteful.

5. I have already referred to the necessity of having the Effluent Farm under the control of canal irrigation. The necessity for canal irrigation would not often occur; and presumably, under a special agreement, a small charge would be made by the Irrigation Department for each watering, as required. When sugarcane is first planted, irrigation is required at short intervals (every three or four days) for two or three weeks, in order to encourage the eyes to produce shoots. Frequent effluent irrigation at this stage might prove harmful. The crop makes slow progress when young, and it is possible that purified sewage, if applied regularly at this stage, might prove too strong for the young plants. There was some indication of this in a plot at the Poona Government Farm. A green mould formed on the surface of the soil, and the young plants became slightly unhealthy. The application of effluent water was stopped for three weeks, and one watering of canal water was given instead. The crop then became, owing to this change, vigorous in growth and exceedingly healthy in colour. Afterwards the effluent irrigation was continued with beneficial effect. Sugarcane, when it has made some progress, is an exceedingly gross feeding crop, requiring much manure and much water; and after it is three months old, I think that even heavy applications of the effluent would be beneficial.

6. The next point to which I wish to direct attention is the probable value of the purified sewage, as a supplier of manure and water, for sugarcane and other crops. As regards its value for sugarcane, we have no conclusive proof yet. All that I can say is, that a plot manured and irrigated with the effluent on the Poona Farm, bears favourable comparison with similar plots heavily and expensively manured with (1) Poudrette, and (2) Farm yard manure, and irrigated with canal water. The value of the effluent for quick growing fodder crops has been clearly demonstrated (see tabulated statement attached to this report).

7. In estimating the probable value of the effluent for sugarcane, we have to consider how much a good cultivator of sugarcane expends on manure and water. Poudrette may be taken as a basis of calculation. When the Poona sewage system is complete, no poudrette will be produced, and purified sewage will be available instead. Poudrette is ordinarily worth about Rs. 7 per ton. I have known it dearer, and cheaper, in recent years. There is now no caste objection to its use, and ordinary labourers freely handle it. It is bulky, and therefore costly to transport. Experiments instituted by the Agricultural Department several years ago, have conclusively proved that poudrette at Rs. 7 per ton is a cheap and effective manure, in comparison with other manures ordinarily available. We have, however, proved that certain oil-cakes, rich in nitrogen, are cheaper and more effective. The sugarcane growers have, at last, appreciated this conclusion; and are now beginning to use safflower, and other cakes, which they did not previously employ. They, however, still depend to a considerable extent upon poudrette for their manure supply. The best crops are grown from an application which costs about Rs. 200 per acre. The cost of canal irrigation will be about

Rs. 50 per acre (the water-rate being Rs. 40 per acre). Irrigation from a well, if bullock and manual labour is charged at the ordinary hiring rates, will exceed Rs. 100 per acre. The cost, therefore, of manure and water for a sugarcane crop will be at least Rs. 250 per acre, and may be more. The question is, can the purified sewage be proved to be a profitable substitute? It probably can, but no decided answer can yet be given. All I can say definitely is, that the effluent is exceedingly quick-acting. I am of opinion also, that if the purification on a large scale is as complete as that produced under the experiments, there will be no fear of injury by irrigation as continuous as that practised with canal, or well water.

8. The quick-acting manurial effect of the purified sewage is not difficult to comprehend. The comparative manure experiments instituted by the Agricultural Department at Manjhri some years ago, proved that nitrogen, in an immediately available form, was the most important plant-food required by sugarcane. The Agricultural Chemist to the Government of India proved by analyses, that a very heavy crop of sugarcane can take up only about 100 pounds of nitrogen per acre; whereas, in practice, we have found that the best results are got from quick-acting manures which, in an application for an acre, contain at least 350 pounds of nitrogen. Less will, undoubtedly, suffice in the case of the effluent, because it would be applied by degrees; and the Manjhri experiments clearly proved that manure was economised when given as a top-dressing, rather than as a full application before plantation. Plants can only take up nitrogen through their roots, in the form of nitrates; and this is the immediately available form. Organic nitrogen, or any unoxidized compound of nitrogen, in the soil is converted into nitrates by Bacterial agency, in a manner which need not here be referred to. The Bacterial treatment of sewage in a septic tank and filter beds induces somewhat similar changes. If purification is complete, the albuminoid nitrogen of sewage is changed so that nitrates are formed. The analyses of samples of the Poona effluent show that purification has not been quite complete, but the purification has so far progressed that the nitrogen has mostly been converted into ammonia salts and nitrites. The further oxidisation of these compounds into nitric acid, or nitrates, would occur rapidly in any Indian soil. Moisture, warmth, and the presence of a mineral base like lime, will accelerate the change. From these facts we may conclude that the effluent is quick acting as a manure; and I can state positively, from observing the effect on a crop, that such is the case.

9. The analyses of the Poona purified sewage show a variable composition. It, however, may be concluded that if nitrogen is present in sufficient quantity for the full requirements of a sugarcane crop, the other important manurial ingredients, such as phosphoric acid and potash, will also be present in sufficient quantity. The analyses show considerable proportions of chlorine; chlorides in large quantities, continuously applied, might prove harmful to vegetation, but I do not anticipate any risk on this account.

10. The analyses being somewhat variable, I have not attempted to work out the actual weight of nitrogen which could be given by irriga-

ting sugarcane for a year with the purified sewage. But it is certain, I think, that the amount will be fully sufficient for the requirements of a heavy crop, but not excessive.

11. I think we may reasonably conclude that the purified sewage can be advantageously employed for certain crops in certain kinds of soil in India. I must, however, make the following reservation, *viz.*, that unless the proposed farm is under the capable supervision of a thoroughly practical agriculturist, with considerable Indian experience, it is extremely likely to prove a dead failure. The Poona Municipality must get its effluent farm in the first instance, and it must also arrange for capable supervision. If the value of purified sewage is fairly demonstrated on such a farm, ordinary cultivators will, in a few years, be found willing to take the stuff, at its value as a source of manure and irrigation; but in this case a Superintendent of proved capabilities need not lose his occupation, as more effluent will be available each year, with the increase in population and water-supply; and be available for sale, unless the Municipality wish to extend their own farm. There is also full scope elsewhere for the sanitary improvement of Indian cities, and the development, on practical lines, of such farms.

12. We ought to investigate with some degree of minuteness the probable cost of growing sugarcane, irrigated by means of purified sewage; and, as a basis of calculation, I give below the details of expenditure incurred in growing newly planted cane at our Manjhri experimental station, in 1898-99. The crop was manured with poudrette. Several of the other comparative plots which had been manured with other kinds of manure, gave better results at less cost. But the outturn from the poudrette plot may be considered a full average for high class cultivation as practised by the best cultivators. The land had been under cultivation with sugarcane for some years. It was in good condition, and a very heavy application of manure was not necessary.

13.

| | Cost of cultivation per acre. Rs. | a. | p. |
|---|---|---|---|
| Preparatory tillage, including ploughing three times, clod crushing, levelling, harrowing, collecting weeds, ridging and forming beds and water channels for irrigation ... ... ... | 42 | 7 | 0 |
| Cost of "sets" and planting ... ... ... ... ... ... | 47 | 8 | 0 |
| Hand weeding (six times during year)... ... ... ... ... | 14 | 1 | 0 |
| Earthing up cane, digging and forming new beds in June and July, by contract ... ... ... ... ... ... ... ... | 9 | 0 | 0 |
| Cost of labour in applying irrigation water; crop irrigated 30 times ... | 9 | 6 | 0 |
| Miscellaneous expenses, proportionate cost of erecting gural, tying up cane, making water-courses, use of cane mill, and watching ... | 14 | 6 | 0 |
| Harvesting cane and making jagri, at contract rate of Re. 1 for each pan boiled ... ... ... ... ... ... ... ... | 65 | 0 | 0 |
| Carting cane from field to gural ... ... ... ... ... | 6 | 2 | 0 |
| Carting jagri to Poona, toll and Municipal taxes ... ... ... | 10 | 4 | 0 |
| | 218 | 2 | 0 |
| Cost of poudrette, carting of same, and application ... Rs. 190 2 0 | | | |
| Charge for canal-water by Irrigation Department ... 40 0 0 | | | |
| | 230 | 2 | 0 |
| Total cost of cultivation ... | 448 | 4 | 0 |
| Yield 10,060 pounds of jagri. Value per acre... ... Rs. | 620 | 9 | 7 |

14. The rate for jagri was very variable. At the beginning of the season (1898-99) it was Rs. 22 and 23 per pullah of 246 pounds. Later in the season the price fell considerably. The average price obtained, fairly early in the season, for the jagri produce of our experimental area was at the rate of 16·21 pounds per rupee ; and the above outturn figures are calculated at that rate. It is fair, however, to notice that within recent years the price has been as low as Rs. 11 or 12 per pullah, when the market was temporarily overstocked ; and at that price, the outturn per acre noted above, would have been worth less than Rs. 500 per acre. Goor is a perishable article, which is difficult to store ; and an ordinary cultivator, having no means of storage for a large quantity, is compelled to sell his produce at once. If the Municipality, on their proposed farm, provide accommodation for storage, and adopt the Guzerath method of storing goor in earthen ware chatty pots, there would be no need to sell the produce at any particular season, and a good market rate could be eventually ensured ; and, therefore, it is certain that Rs. 15, or more, per pullah, for their goor would always be obtained. At that price, an acre of good sugarcane would leave a *clear* net profit of from Rs. 300 to 400 per acre, if the value of manure and water, or purified sewage, is left out of account. A good crop of Ratoon cane (which is grown at considerably less cost), would, I think, be quite as profitable, if not more so.

15. I have already referred to the experiments conducted at the Poona Government Farm to test the effect of the effluent on various fodder-crops. The crops which were selected for experiments had been thoroughly tested on the Farm in previous years, on various descriptions of soil ; and it had been proved that they yielded heavily, matured quickly, and produced excellent fodder, on almost any kind of soil in good condition, in a favourable season. The soil of the field selected was light, and of fair depth. It was also clean ; but only in moderate condition, no manure having been applied during the two previous years. Two of the experimental crops (lucerne and guinea-grass) are perennial ; and the cost of sowing, or planting, is heavy as compared with the preparatory tillage for the other crops. Lucerne will, however, yield 12 cuttings during a year, and guinea-grass 8 cuttings; so that the heavy initial outlay can soon be recovered. The other crops grow so quickly that certainly three, and probably four crops could be grown in succession, with effluent irrigation, in the course of a year. The frequent cultivation of the same crop on the same land might be objected to, as likely to induce an unhealthy condition. That objection would be overcome by a capable Manager, who would find it advantageous to practise rotation of crops. Various pulse crops, such as wal, chola, udid, mug, &c., would be excellent for the purpose. These pulse crops would, I think, thrive under effluent irrigation, and might be allowed to grow to maturity ; or the pods might be plucked early, and sold as green vegetables, and the fodder cut green.

16. The experimental plots treated with the purified sewage were

thrice irrigated with it. Although the extent of this irrigation was not great, the effluent was strong ; stronger in fact than would be the case in actual practice on a large scale ; and I concluded from the vigour of growth, and general appearance of the crops, that the soil had received sufficient to bring the crops to maturity. Canal water, in addition to the effluent, was given as required. The chief object of the experiment was to test the value, on light soil, of purified sewage in comparison with heavy dressings of poudrette and Farm yard manure.

17. I epitomize the results in the appended tabulated statement. The plan of experiment can be clearly seen from it.

J. A. MOLLISON,
*Deputy Director*
*of Agriculture.*

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*Analysis of Poona Sewage Effluent, by the Chemical Analyser to Government on 26th July* 1899.

| "A" from Coke Filter. "B" from Clinker " | Parts per 100,000. A | B |
|---|---|---|
| Chlorine ... ... ... ... ... ... ... | 15·50 | 15·80 |
| Ammonia ... ... ... ... ... ... ... | 7·50 | 9·00 |
| Albuminoid Ammonia ... ... .... ... ... | 0·32 | 0·36 |
| Nitrites ... ... ... ... ... ... ... | 11·50 | 28·75 |
| Total solids .... ... ... ... ... ... ... | 67·00 | 80·00 |
| Oxygen absorbed in 4 hours... ... ... ... ... | 15·20 | 19·20 |

*N.B.*—The Crude Sewage Mixture, put into the Septic Tank, consisted of:—

| | | |
|---|---|---|
| Solid Nightsoil ... ... ... ... | 8½ | pounds. |
| Urine ... ... ... ... ... ... | 6 | gallons. |
| Water ... ... ... ... ... | 490 | do. |

representing the ordinary town sewage, (with a water supply of 15 gallons per head) of 33 persons. This was kept in the Tank for 24 hours, and in the Filters for 2 hours, and then the above effluent was drawn off. The Tank effluent has a *very* slight odour ; but the Filter effluent has none whatever. Daily samples have been stored in bottles since the beginning of May, but none of them have shown the slightest signs of secondary decomposition during the ensuing three months.

*Comparative Manure and Irrigation Experiments with various Fodder Crops ; all Crops sowed, or planted, on 8th May 1899.*

| Manure. | Crop. | Date of Harvesting. | Outturn per Acre. | Cost of Cultivation per Acre. | Gross Value of Outturn per Acre. | Remarks. |
|---|---|---|---|---|---|---|
| | | | Lbs. | Rs. a. p. | Rs. a. p. | |
| Irrigated four times with the effluent. The water of the 81,500 gallons of sewage being equal to, approximately, 4" of rainfall. | Guinea-grass ... | 30th June ... | 6,160 | 70 4 8 | 93 8 0 | When fairly established, this crop will yield eight cuttings in a year. It requires plenty of manure and water, and seems to thrive uncommonly well under effluent irrigation. Worth, in Poona, 150 lbs. per rupee. |
| | 2nd cutting ditto ... | 5th Aug. ... | 7,868 | | | |
| | 3rd ditto ... ... | 2nd Sept. ... | 6,216 | 5 15 8 | 41 7 0 | The third cutting had to be made prematurely for this report; but the weight can be compared with the time of growth. |
| | Lucerne ... | 18th July ... | 4,564 | 91 0 0 | 141 6 0 | Can be cut 12 times in a year. The first cutting was, as usual, insignificant. The rapidity with which the crop produced a 2nd cutting is noteworthy. Lucerne is easily saleable in Poona at 100 lbs. per rupee. |
| | 2nd cutting ditto ... | 7th Aug. ... | 9,576 | | | |
| | 3rd ditto ... ... | 3rd Sept. ... | 7,364 | 5 15 8 | 73 10 0 | As regards the third cutting, see Note above. |
| | Sundhia Jowar ... | 1st July ... | 22,316 | 16 10 0 | 89 4 0 | This fodder is valued at 250 lbs. per rupee, but would probably be easily saleable at a dearer rate. Stalks very long and very fine. Cut in full flower, 53 days after sowing. Four crops in succession can easily be grown in a year. The second crop from the stubble shows that it would be better to sow fresh seed each time. |
| | 2nd cutting ... ... | 30th Aug. ... | 10,164 | 15 5 0 | 40 10 0 | |
| | Nilwa Jowar ... | 4th Aug. ... | 32,536 | 22 0 4 | 108 7 0 | Stalks coarser than Sundhia, and not worth so much as fodder. Valued at 300 lbs. per rupee. Took 88 days between seed time and harvest. Cut when in flower. Only three crops, at most, could be taken in a year. |
| | Second growth promising. | | | | | |
| | American Sorghum ... (Amber variety.) | 13th July ... | 36,764 | 18 8 4 | 122 8 0 | An excellent fodder, equal in value at least to Nilwa. Matures quickly. Cut 66 days after sowing. Valued at 300 lbs. per rupee. This fodder is very sweet, and has much leaf growth. |
| | Second growth promising | | | | | |
| | American Sorghum ... (Collier variety.) | 18th July ... | 34,188 | 21 2 4 | 114 0 0 | Was reaped 71 days after sowing. Other remarks same as for the Amber variety. |
| | Second growth promising. | | | | | |
| | Maize ... ... | 15th July ... | 51,576 | 27 9 0 | 129 0 0 | An extraordinary heavy crop, which was reaped 68 days after sowing. Stalks very coarse. Fodder valued at 400 lbs. per rupee, and doubtful whether it would be readily saleable at that price; but the corn itself would be valuable as maize. |

*Comparative Manure and Irrigation Experiments with various Fodder Crops; all Crops sowed, or planted, on 8th May 1899.—(continued.)*

| Manure. | Crop. | Date of Harvesting. | Outturn per Acre. | Gross Value of Outturn per Acre. | Remarks. |
|---|---|---|---|---|---|
| | | | lbs. | Rs. a. p. | |
| Manured with 20 tons Farm yard manure per acre, and irrigated as required with canal water. | Guinea-grass ... ... | 1st July ... | 3,752 | 61 3 0 | Farm yard manure showed, as usual under irrigation, a slow acting effect. The value of the manure will be better seen in subsequent crops. The 2nd cuttings of Lucerne and Guinea-grass indicate that these crops are now getting benefit from the manure applied. Second growth of Nilwa and Sorghums very poor. |
| | 2nd cutting ... ... | 5th August ... | 5,432 | | |
| | 3rd ditto ... ... | 2nd Sept. ... | 4,788 | 31 15 0 | |
| | Lucerne ... ... | 19th July ... | 3,472 | 115 0 0 | |
| | 2nd cutting ... ... | 7th August ... | 8,036 | | |
| | 3rd ditto ... ... | 3rd Sept. ... | 6,440 | 64 7 0 | |
| | Sundhia Jowar ... | 3rd July ... | 12,992 | 52 0 0 | |
| | 2nd cutting ... ... | 31st Aug. ... | 5,824 | 23 4 0 | |
| | Nilwa Jowar ... ... | 6th August ... | 19,348 | 64 8 0 | |
| | Sorghum (Amber) ... | 21st July ... | 20,580 | 68 10 0 | |
| | Sorghum (Collier) ... | 24th July ... | 16,688 | 55 10 0 | |
| | Maize ... ... ... | 17th July ... | 17,724 | 44 5 0 | |
| Manure per acre 20 tons Poudrette, with irrigation from the canal as required. | Guinea-grass ... ... | 2nd July ... | 5,040 | 96 11 0 | These figures show that only in the case of Lucerne are the outturn results better than in the effluent plots. The inferences to be drawn are, that the effluent is extremely quick acting; and is more valuable as a direct application, than a heavy and expensive dressing of Poudrette. The effect of the Poudrette will, like that of Farm yard manure, extend to future crops. This is evidenced to some extent by the heavy 2nd cut obtained from the Lucerne plot. Second growth of Nilwa and Sorghums poor. |
| | 2nd cutting ... ... | 5th August ... | 9,464 | | |
| | 3rd ditto ... ... | 3rd Sept. ... | 9,128 | 60 13 0 | |
| | Lucerne ... ... | 19th July ... | 6,188 | 182 13 0 | |
| | 2nd cutting ... ... | 7th August ... | 12,096 | | |
| | 3rd ditto ... ... | 3rd Sept. ... | 8,848 | 88 8 0 | |
| | Sundhia Jowar ... | 6th July ... | 21,980 | 87 15 0 | |
| | 2nd cutting ... ... | 31st Aug. ... | 8,932 | 35 11 0 | |
| | Nilwa Jowar ... ... | 4th August ... | 32,760 | 109 3 0 | |
| | Sorghum (Amber) ... | 20th July ... | 34,076 | 113 9 0 | |
| | Sorghum (Collier) ... | 24th July ... | 33,460 | 111 8 0 | |
| | Maize ... ... ... | 16th July ... | 35,070 | 87 11 0 | |

*Note.*—The cost of cultivation, and rates per rupee, are as shown on previous page.

APPENDIX—**C.**

ABSTRACT

OF

# CITY DRAINAGE SCHEME

FOR

## Septic Tank Project.

## Recapitulation of Estimates.

| Estimate No. | | Amount Rs. |
|---|---|---|
| 1 | Laying pipe and masonry sewage lines, and Inverted Syphon under Railway ... ... ... ... ... ... | 5,56,486 |
| 2 | Constructing 965 Manholes... ... ... ... ... ... | 1,31,522 |
| 3 | „ 113 Flushing Manholes ... ... ... ... | 17,391 |
| 4 | „ 44 Automatic Flushing Tanks ... ... ... | 22,229 |
| 5 | „ 1 Automatic Flushing Tank of 6,000 gallons capacity. | 2,256 |
| 6 | „ 1 ditto ditto 22,000 ditto ... | 3,677 |
| 7 | „ 45 Five-inch Inlet Ventilating shafts ... ... | 869 |
| 8 | „ 6 Twelve-inch Outlet do. do. ... ... | 1,793 |
| 9 | Laying Cast-Iron pipes for Sewage Mains ... ... ... | 95,865 |
| 10 | „ „ „ „ Air Mains ... ... ... ... | 37,804 |
| 11 | Inverted Syphon (24″ Cast-Iron pipes) across Nagzeri Nalah ... | 37,990 |
| 12 | Constructing Air Compressing Station ... ... ... ... | 17,876 |
| 13 | „ 4 Ejector Stations ... ... ... ... ... | 10,719 |
| 14 | „ Chimney Shaft ... ... ... ... ... | 9,290 |
| 15 | „ 8 Septic tanks and 16 Filter beds, and Iron work. | 5,50,544 |
| 16 | Machinery of Ejectors, Air Compressing Plant, and Ventilating Shafts, &c. | 3,54,750 |
| 17 | Three-fourths share of Land Compensation for Outfall works ... | 36,000 |
| | Total ... | Rs. 18,87,061 |
| *Deduct—* | | |
| | ¼ of the cost of Septic tanks and Filters ... ... ... ... | 1,37,636 |
| | Difference of cost between a 42″ and 39″ sewer 1,760 feet long ... | 554 |
| | Difference of cost between a 27″ and 24″ Inverted Syphon 1,260 feet long, under the G. I. P. Railway ... ... ... ... ... | 5,040 |
| | Total deduction ... | Rs. 1,43,230 |
| | Total after deduction ... | Rs. 17,43,831 |
| | Establishment charges, and Tools and Plant, at Rs. 4 per cent. ... | 69,753 |
| | Grand Total... ... | Rs. 18,13,584 |

ABSTRACT

OF

# ALTERNATIVE POONA CITY DRAINAGE PROJECT

WITH

## SEWAGE FARM AT SITE No. 3.

| | Rs. |
|---|---|
| Primary and Secondary Sewers, Manholes, Flushing Tanks, and Masonry of Ventilating Shafts ; but excluding masonry of Major Collecting Sewer | 6,45,211 |
| Air and Sewage Mains, Sluice and other Valves, &c. ... ... ... | 2,01,948 |
| Inverted Syphon for Nagzeri Nallah ... ... ... ... ... | 37,990 |
| Air Compressing Plant, Ejectors and Ventilating Shafts ... ... ... | 2,40,000 |
| Engine House for Air Compressing Plant ... ... ... ... ... | 17,876 |
| Chimney Shaft ... ... ... ... ... ... ... ... | 9,290 |
| Four Ejector Chambers ... ... ... ... ... ... ... | 10,719 |
| Major Collecting Sewer ... ... ... ... ... ... ... | 91,012 |
| Share of Rising Main to Farm (cost of 22-inch) ... ... ... ... | 2,70,000 |
| Three-fourths share of Sewage Farm ... ... ... ... ... | 2,25,000 |
| Ditto of Pumping Engines and Engine House, Covered Reservoirs and Grit Chambers ... ... ... ... ... ... | 2,40,000 |
| Total ... Rs. | 19,89,046 |
| Establishment, and Tools and Plant, at 4 per cent. ... ... ... | 79,562 |
| Add yearly instalments on loans for three years of construction ... ... | 1,50,000 |
| Total ... Rs. | 22,18,608 |

*Working Expenses.*

| | |
|---|---|
| Share of Pumping to Farm... ... ... ... ... ... ... | 21,000 |
| Coal, &c., for Air Compressors ... ... ... ... ... ... | 8,000 |
| Repairs and Supervision ... ... ... ... ... ... ... | 3,000 |
| Total ... Rs. | 32,000 |

# ABSTRACT.

| Quantity. | Items. | Rate. | Per | Amount. | |
|---|---|---|---|---|---|
| | | Rs. a. | | Rs. | dec. |
| | *Estimate for Laying Sewage pipes, etc., in the City of Poona—* | | | | |
| ..... | Excavation ... ... ... | ..... | ... | 97,444 | ... |
| ..... | Refilling trenches and making up road surface ... ... ... | ..... | ... | 24,361 | ... |
| 1,52,118 r. ft. | Laying 7″ glazed stoneware pipes.. | | | | |
| 45,097 „ | „ 9″ „ „ ... | | | | |
| 18,767 „ | „ 12″ „ „ ... | | | | |
| 4,049 „ | „ 15″ „ „ ... | | | | |
| 8,581 „ | „ 18″ „ „ ... | ..... | ... | 3,60,925 | ... |
| 519 „ | „ 21″ cast-iron spigot and socket pipes ... | | | | |
| 1,260 „ | „ 27″ cast-iron turned and bored pipes ... | | | | |
| ..... | Culvert for pipes under G. I. P. Railway line ... ... ... | ..... | ... | 1,000 | ... |
| ..... | Cement moulded concrete in 39″ and 42″ Sewers, including centerings ... ... ... ... | ..... | ... | 46,216 | ... |
| ..... | Raising road, Sections Nos. 11 and 15 ... ... ... ... | ..... | ... | 40 | ... |
| | | Total ... Rs. | | 5,29,986 | ... |
| | | *Add*—Contingencies at 5 per cent... „ | | 26,499 | ... |
| | | Grand Total ...Rs. | | 5,56,486 | ... |
| | *Estimate for* 965 *Ordinary Manholes on the Sewer lines for the City of Poona—* | | | | |
| 9 | Manholes 3′ deep... ... ... | 95 0 | each. | 855 | ... |
| 48 | „ 4′ „ ... ... ... | 102 0 | „ | 4,896 | ... |
| 149 | „ 5′ „ ... ... ... | 109 0 | „ | 16,241 | ... |
| 221 | „ 6′ „ ... ... ... | 116 0 | „ | 25,636 | ... |
| 128 | „ 7′ „ ... ... ... | 124 0 | „ | 15,872 | ... |
| 100 | „ 8′ „ ... ... ... | 131 0 | „ | 13,100 | ... |
| 90 | „ 9′ „ ... ... ... | 138 0 | „ | 12,420 | ... |
| 61 | „ 10′ „ ... ... ... | 145 0 | „ | 8,845 | ... |
| 39 | „ 11′ „ ... ... ... | 152 0 | „ | 5,928 | ... |
| 30 | „ 12′ „ ... ... ... | 160 0 | „ | 4,800 | ... |
| 28 | „ 13′ „ ... ... ... | 167 0 | „ | 4,676 | ... |
| 18 | „ 14′ „ ... ... ... | 174 0 | „ | 3,132 | ... |
| 12 | „ 15′ „ ... ... ... | 181 0 | „ | 2,172 | ... |
| 4 | „ 16′ „ ... ... ... | 188 0 | „ | 752 | ... |
| 6 | „ 17′ „ ... ... ... | 196 0 | „ | 1,176 | ... |
| 7 | „ 18′ „ ... ... ... | 203 0 | „ | 1,421 | ... |
| 5 | „ 19′ „ ... ... ... | 210 0 | „ | 1,050 | ... |
| 4 | „ 20′ „ ... ... ... | 217 0 | „ | 868 | ... |
| 1 | „ 21′ „ ... ... ... | 224 0 | „ | 224 | ... |
| 2 | „ 22′ „ ... ... ... | 232 0 | „ | 464 | ... |
| 2 | „ 23′ „ ... ... ... | 239 0 | „ | 478 | ... |
| 1 | „ 25′ „ ... ... ... | 253 0 | „ | 253 | ... |
| | | Total ... Rs. | | 1,25,259 | ... |
| | | *Add*—Contingencies at 5 per cent... „ | | 6,263 | ... |
| | | Grand Total ...Rs. | | 1,31,522 | ... |

# ABSTRACT.

| Quantity. | Items. | Rate. | Per | Amount. | |
|---|---|---|---|---|---|
| | *Estimate for* 113 *Flushing manholes of various depths, at heads of short lengths of Sewers of the Poona Drainage Scheme—* | Rs. a. | | Rs. | dec. |
| 7 | Flushing manholes 4′ deep ... | 135 0 | each | 945 | ... |
| 59 | ,, ,, 5′ ,, ... | 142 0 | ,, | 8,378 | ... |
| 29 | ,, ,, 6′ ,, ... | 149 0 | ,, | 4,321 | ... |
| 12 | ,, ,, 7′ ,, ... | 156 0 | ,, | 1,872 | ... |
| 2 | ,, ,, 8′ ,, ... | 164 0 | ,, | 328 | ... |
| 2 | ,, ,, 9′ ,, ... | 171 0 | ,, | 342 | ... |
| 1 | ,, ,, 10′ ,, ... | 178 0 | ,, | 178 | ... |
| 1 | ,, ,, 13′ ,, ... | 199 0 | ,, | 199 | ... |
| | | Total ... Rs. | | 16,563 | ... |
| | *Add*—Contingencies at 5 per cent.... ,, | | | 828 | ... |
| | | Grand Total...Rs. | | 17,391 | ... |
| | *Estimate for* 44 *Automatic Flushing Tanks at heads of* 7″ *and* 9″ *Sewers of the Poona Drainage Scheme—* | Rs. a. | | | |
| 31 | Automatic Flushing tanks of 500 gallons capacity... ... ... | 451 0 | each | 13,981 | ... |
| 13 | Automatic Flushing tanks of 1,000 gallons capacity ... ... ... | 553 0 | ,, | 7,189 | ... |
| | | Total ... Rs. | | 21,170 | ... |
| | *Add*—Contingencies at 5 per cent.... ,, | | | 1,059 | ... |
| | | Grand Total ... ,, | | 22,229 | ... |
| | *Estimate for* 8 *Septic Tanks and* 16 *Filters, for purification of the Sewage of Poona, near the Outfall—* | Rs. a. | | | |
| ..... | Excavation... ... ... ... | ..... | ... | 27,751 | ... |
| ..... | Concrete filling ... ... ... | ..... | ... | 63,817 | ... |
| ..... | Stone and lime masonry 2nd class... | ..... | ... | 86,225 | ... |
| ... .. | Concrete vaulting, including centering ... ... ... ... | ..... | ... | 32,080 | ... |
| ..... | Furnace clinker, or burnt clay ballast, for filters ... ... ... | ..... | ... | 99,688 | ... |
| ..... | Earth filling ... ... ... | ..... | ... | 369 | ... |
| ..... | Forming conduits in filter floors ... | ..... | ... | 317 | ... |
| ..... | Roof coverings of four Admission Valve Chambers ... ... | ..... | ... | 960 | ... |
| | Levelling ground ... ... | ..... | ... | 142 | ... |
| 9,504 r. ft. | 12″ stoneware pipes, main distributors... | | | | |
| 5,760 ,, | 9″ ,, ,, ,, ... | ..... | ... | 1,00,172 | ... |
| 31,200 ,, | 6″ channel stoneware pipes, branch distributors ... ... ... | | | | |
| 1 25,504 ,, | 3″ stoneware pipes, branch collectors | | | | |
| ..... | Iron work and machinery complete. | ..... | ... | 1,00,000 | ... |
| ..... | Cement plaster, ½″ thick ... ... | ..... | ... | 12,807 | ... |
| | | Total... Rs. | | 5,24,328 | ... |
| | *Add*—Contingencies at 5 per cent.... ,, | | | 26,216 | ... |
| | | Grand Total ...Rs. | | 5,50,544 | ... |

# ABSTRACT

OF

# CANTONMENT DRAINAGE SCHEME

FOR

## SEPTIC TANK PROJECT.

| | | Rs. |
|---|---|---|
| Total of works in Cantonments ... ... ... ... ... | | 1,41,858 |
| Add one-fourth cost of Septic Tank and Filters ... ... ... | | 1,37,636 |
| Extra cost of Outfall Sewer, from junction of Cantonment Main Sewer with City Major Collecting Sewer ... ... ... ... | | 5,594 |
| One-fourth share of Land Compensation for Outfall works ... ... | | 12,000 |
| Total ... Rs. | | 2,97,088 |
| Establishment, and Tools & Plant, at 4 per cent. ... ... ... | | 11,884 |
| Grand Total ... Rs. | | 3,08,972 |
| 2,400 House connections, at Rs. 125 ... ... ... ... Rs. | | 3,00,000 |

A tax of Rs. 10 per annum for each house will cover the interest at 5 per cent. and Sinking Fund for 20 years on this latter amount. To cover Contingencies, the rate may be one rupee per month for each Connection and Water Closet.

WORKING EXPENSES.

| | |
|---|---|
| Repairs and Supervision ... ... ... ... ... Rs. | 1,000 |

# ABSTRACT

OF

# ALTERNATIVE PROJECT FOR CANTONMENT DRAINAGE PROJECT

WITH

## SEWAGE FARM AT SITE No. 3.

| | Rs. |
|---|---|
| Sewers, &c., as before ... ... ... ... ... | 1,41,858 |
| 2,100 feet extra 18-inch sewer to junction ... ... | 12,600 |
| Difference between 39 and 42-inch sewer from junction to Outfall ... ... ... ... ... ... | 3,210 |
| One-fourth of Machinery and Works at Outfall ... | 80,000 |
| Difference between 22 and 24-inch Cast-iron Rising Main to Farm ... ... ... ... ... | 36,000 |
| One-fourth share of Sewage Farm ... ... ... | 75,000 |
| | 3,48,668 |
| Establishment, and Tools and Plant, at 4 per cent. ... | 13,947 |
| Total ... Rs. | 3,62,615 |

WORKING EXPENSES.

| | |
|---|---|
| Share of Pumping to Farm ... ... ... ... | 7,000 |
| Repairs and Supervision ... ... ... ... | 1,000 |
| Total ... Rs. | 8,000 |

# ABSTRACT.

| Quantity. | Items. | Rate. | Per. | Amount. |
|---|---|---|---|---|
| | *Cantonment Drainage Scheme.* | Rs. a. | | Rs. dec. |
| | Estimate for Laying pipe sewers, constructing ordinary and flushing manholes and Automatic flushing tanks and inlet ventilating shafts in the Cantonment of Poona in connection with the Drainage Scheme. | | | |
| | Excavation... ... ... ... | ..... | ... | 19,245 ... |
| | Refilling trenches and making up road surface ... ... ... | ..... | ... | 4,811 ... |
| 36,683 r.ft. | Laying 7″ stoneware pipe ... | ..... | ... | |
| 4,130 „ | „ 9″ do. do. ... | ..... | ... | |
| 3,520 „ | „ 12″ do. do. ... | ..... | ... | 77,203 ... |
| 1,020 „ | „ 15″ do. do. ... | ..... | ... | |
| 3,710 „ | „ 18″ do. do. ... | ..... | ... | |
| 7 No. | Manholes 3 feet deep ... ... | 95 0 | each. | 665 ... |
| 11 „ | „ 4 „ „ ... ... | 102 0 | „ | 1,122 ... |
| 33 „ | „ 5 „ „ ... ... | 109 0 | „ | 3,597 ... |
| 26 „ | „ 6 „ „ ... ... | 116 0 | „ | 3,016 ... |
| 22 „ | „ 7 „ „ ... ... | 124 0 | „ | 2,728 ... |
| 26 „ | „ 8 „ „ ... ... | 131 0 | „ | 3,406 ... |
| 14 „ | „ 9 „ „ ... ... | 138 0 | „ | 1,932 ... |
| 11 „ | „ 10 „ „ ... ... | 145 0 | „ | 1,595 ... |
| 6 „ | „ 11 „ „ ... ... | 152 0 | „ | 912 ... |
| 5 „ | „ 12 „ „ ... ... | 160 0 | „ | 800 ... |
| 5 „ | „ 13 „ „ ... ... | 167 0 | „ | 835 ... |
| 3 „ | „ 14 „ „ ... ... | 174 0 | „ | 522 ... |
| 3 „ | „ 16 „ „ ... ... | 188 0 | „ | 564 ... |
| 1 „ | „ 19 „ „ ... ... | 210 0 | „ | 210 ... |
| 1 „ | „ 20 „ „ ... ... | 217 0 | „ | 217 ... |
| 12 „ | Flushing Manholes, 5 ft. deep ... | 142 0 | „ | 1,704 ... |
| 6 „ | „ „ 6 ft. „ ... | 149 0 | „ | 894 ... |
| 12 „ | Automatic flushing tanks 6′ average depth, at heads of 7″ sewers ... | 451 0 | „ | 5,412 ... |
| 1 „ | Automatic flushing tank 5′ average depth, at the heads of 9″ sewers | 553 0 | „ | 553 ... |
| 13 „ | 5″ Inlet Ventilating shafts... ... | 18 0 | „ | 234 ... |
| 13 „ | 5″ Cast-Iron pipes for ventilation of above, with adjustable caps ... | 225 0 | „ | 2,925 ... |
| | | | Total...Rs. | 1,35,103 ... |
| | | | Add Contingencies at 5 per cent....Rs. | 6,755 ... |
| | | | Grand Total ... | 1,41,858 ... |

ESTIMATE

FOR

# HOUSE CONNECTIONS

## and additions to existing Privies to turn them into Water Closets.

| | | Rs. |
|---|---|---|
| 1 | "Hindustan" pattern pan, with polished top and foot rests, and trap. | |
| 1 | 3-gallon Syphon Flushing tank with ball cock, fitted on brackets 12″ × 4″ × 4″ by screws, and fixed to teak wall blocks ... | |
| 8 | Ft. of 1½ inch lead pipe from tank to pan ... ... ... | 92 |
| | Plumber's work, and fixing pan on trap with red lead ... ... | |
| 1 | India-rubber cone, with red lead and binding wire, &c., to make joint of pipe to pan water tight; and clamp to fix pipe to wall. | |
| | Ventilating and anti-syphonage pipes ... ... ... ... | 7 |
| | Water connection to tank ... ... ... ... ... | 8 |
| | Masonry work for privies, as at Ahmedabad, say ... ... | 18 |
| | Total... Rs. | 125 |

ESTIMATE

FOR

# EFFLUENT FARM

## NEAR HADAPSAR.

*Revised in accordance with Mr. Mollison's suggestions.*

| | | Rs. |
|---|---|---|
| | Land compensation for 925 acres, including the necessary buildings, &c. ... ... ... ... ... ... ... | 4,00,000 |
| 34,000 | Feet of 24-inch Cast-iron Rising Main, including laying, with all Reflux and Sluice Valves, and Masonry Distributaries ... | 5,00,000 |
| | Pumping Machinery, including erection, and Engine House ... | 2,70,000 |
| | An open Storage Reservoir at each end; each reservoir consisting of two Compartments, each 100×100×11 feet .. ... | 30,000 |
| | Total .. Rs. | 12,00,000 |

APPENDIX—**D**.

# FINANCIAL STATEMENT.

EXPENDITURE
ON
## DRAINAGE SCHEME.

| | | | |
|---|---|---|---|
| 1st Year— | | £ | |
| Stoneware pipes ... ... ... ... | | 13,000 | To be purchased in England, f. o. b. Bombay. |
| Air and Sewage Mains and Valves ... | | 15,000 | |
| Machinery and Ejectors, &c. ... ... | | 16,000 | |
| Fittings for Septic Tanks and Filters ... | | 6,000 | |
| | | | Rs. |
| Total ... | £50,000, say | | 7,50,000 |
| Customs Duty and carriage of above ... ... ... | | | 64,000 |
| Engine House, Chimney, Tanks and Filters ... ... | | | 2,00,000 |
| Land Compensation ... ... ... ... ... | | | 36,000 |
| Total ... Rs. | | | 10,00,000 |
| 2nd Year— | | | |
| Pipe-laying and Manholes, &c. ... ... ... | | | 3,50,000 |
| Machinery and Ejectors, Erection, &c. ... ... | | | 1,00,000 |
| Fittings for Tanks and Filters ... ... ... | | | 40,000 |
| Local work on do. and Engine House and Chimney... | | | 1,60,000 |
| Total ... Rs. | | | 6,50,000 |
| 3rd Year— | | | |
| Completion of Pipe-laying, &c. ... ... ... | | | 1,63,000 |
| Grand Total ... Rs. | | | 18,13,000 |

### EFFLUENT FARM.

*Revised in accordance with Mr. Mollison's report.*

| | | |
|---|---|---|
| 1st Year— | | |
| Machinery and Engine House ... ... | Rs. | 1,00,000 |
| 2nd Year— | | |
| Machinery and Engine House ... ... ... | | 1,00,000 |
| Rising Main ... ... ... ... ... | | 3,00,000 |
| Total... | Rs. | 4,00,000 |
| 3rd Year— | | |
| Machinery and Erection and Engine House... ... | | 70,000 |
| Rising Main ... ... ... ... ... ... | | 2,00,000 |
| Storage Reservoirs ... ... ... ... ... | | 30,000 |
| Land Compensation, Farm buildings, &c. ... ... | | 4,00,000 |
| Total... | Rs. | 7,00,000 |
| Grand Total... | Rs. | 12,00,000 |

## LOANS REQUIRED.

| | | Rs. |
|---|---|---|
| 1st Year— | | |
| Drainage Scheme ... ... ... ... ... | | 10,00,000 |
| Farm ... ... ... ... ... ... ... | | 1,00,000 |
| | Total... Rs. | 11,00,000 |
| 2nd Year— | | |
| Drainage Scheme ... ... ... ... ... | | 6,50,000 |
| Farm ... ... ... ... ... ... ... | | 4,00,000 |
| Interest and Sinking Fund on 11 lakhs of 1st year, at 5 per cent. for 30 years, say ... ... ... | | 70,000 |
| | Total... Rs. | 11,20,000 |
| 3rd Year— | | |
| Drainage Scheme ... ... ... ... ... | | 1,63,000 |
| Farm ... ... ... ... ... ... ... | | 7,00,000 |
| Interest and Sinking Fund on 22 lakhs of 1st and 2nd years, say... ... ... ... ... ... | | 1,43,000 |
| | Total... Rs. | 10,06,000 |
| | Grand Total, say... Rs. | 32,26,000 |
| 4th Year— | | |
| Interest and Sinking Fund on above total ... ... | | 2,09,851 |
| Working expenses, including pumping to Farm and Air Compressing... ... ... ... ... | | 33,000 |
| | Total say... Rs. | 2,43,000 |

### NET REVENUE FROM FARM.

*Revised in accordance with Mr. Mollison's Report.*

| | | |
|---|---|---|
| 550 acres sugarcane at Rs. 300 ... ... ... | | 1,65,000 |
| 275 „ Fodder crops at Rs. 150 ... ... ... | | 41,250 |
| 100 „ „ „ „ 100 ... ... ... | | 10,000 |
| Saving on Poudrette manufacture ... ... ... | | 40,000 |
| | Total... Rs. | 2,56,250 |
| Net profit per annum for Drainage Scheme after completion, and allowing for cost of Farm Superintendent, and his Office ... ... ... ... Rs. | | 7,000 |

*N.B.*—No account is taken of the 10 lakhs which will have to be borrowed in the 3rd year for House Connections, as the Interest and Sinking Fund on it (which will be due in the next and succeeding years), will be more than covered by the rate to be levied on the houses served, at one rupee per month.

## APPENDIX **E.**

## Remarks on Poona Sewerage and Sewage Disposal, by Colonel W. M. Ducat, R. E., Late Deputy Chief Engineer Inspector, Local Government Board, London.

As a past Executive Engineer, Poona, and one who designed a scheme of sewerage and sewage disposal for the City, I may, perhaps, be allowed to offer the following remarks on the sanitary works there, which, I understand, are now in contemplation.

For very many years past the principal streets and roads in the City of Poona have been provided with sewers, or drains, of the worst possible description; *viz.*, old stone-built drains, rectangular in section, without any pretension to being water-tight, and with almost every defect of fall, ventilation, inspection, flushing, &c., that a sewer can have. I have seen some of these sewers opened, and found them absolutely full to the surface with sewage sludge in an advanced and most offensive and dangerous state of decomposition. So long as these old Sewers remain permeating the City, acting as Gas retorts for the distillation of most deadly sewer gases; and the subsoil around them, on which dwelling houses stand, is saturated with leakage from them; the City of Poona can never be a safe place to live in; and it will be impossible to eradicate any plague, or disease, that has once taken hold of the place; so that it is indeed well that Government has taken the matter in hand, and intend to have the City properly sewered.

Whether the scheme of sewerage to be adopted be that I gave to the City some 15 years ago, or whether a revised scheme has been prepared, the general outline must be much the same; and the cheapest and most convenient site for the outfall must be the land lying between the Sassoon Hospital, the Sungum, and the River. On this land, unless it has been much curtailed by building operations since I knew it, there is space enough for a pumping station, purification works, and everything necessary for the effective and inoffensive disposal of the sewage of the City. The pumping station should be placed well in the centre of the plot of land, so as to be as far as possible from the Hospital, the public road, or the river; but if the works are properly designed, there should be no offence from them, and no danger whatever to health.

The method of disposal of the sewage requires careful consideration. On no land in, or around Poona, will it be desirable to use *crude* sewage for irrigation purposes; either from the point of view of purifying the sewage on the land, or the utilization of the value of sewage for irrigation. In all sewage there is a considerable amount of solid matter, or sludge, and this solid matter is liable to collect on the surface of heavy land, such as that near Poona, and form a coating which will interfere with the oxidisation of the soil below; and thus prevent the nitrification and purification of the sewage, through the land; and the sludge itself, adhering to the growing crops on the land, might become a serious source of danger to health. To ensure the absolutely safe and efficient disposal of the sewage, it should first be purified through an aërated bacterial self-acting filter; by means of which all the organic putrescible matter in the sewage (which constitutes the danger in the case of mere broad irrigation with crude sewage), is converted into Nitrate Salts, no longer putrescible, or objectionable, yet still containing all the manurial value of the crude sewage. The effluent from an aërated bacterial filter can thus be turned direct into any stream without the least objection, or offence; or it can, when so desired, be used most advantageously for irrigation, without the slightest risk, no matter how dangerous the original sewage may have been.

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